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Zeoponic: A Breakthrough Plant Growth Media for Horticulture and Seedling of Plantation

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ABSTRACT

Background: Plant growth media (PGM) play a crucial role in supporting plant growth and development. The choice of high-quality growing media is essential to provide the necessary nutrients and support for optimal plant growth. This study compares the physical and chemical properties of zeoponic with commercial PGMs.

Methods: The study was conducted from September 2021 to March 2022 at the Cikabayan Education greenhouse, Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University. Laboratory analysis of the physical and chemical properties of PGM was conducted with parameters such as pH, electrical conductivity (EC), nutrient content, bulk density, cation exchange capacity (CEC) and base saturation and also plant growth parameters such as plant height, stem diameter, number of leaves, leaf length and leaf width were measured.

Result: The results show that zeoponic has a neutral pH, low EC value and high CEC, indicated that the use of zeoponic led to significantly greater plant height, stem diameter, number of leaves, leaf length and leaf width in all types of plants than commercial PGMs. Unique physical and chemical properties in zeoponic create an ideal environment for root development and nutrient absorption. Therefore, zeoponic demonstrates superior performance as a PGM for various plant types, including horticultural crops and seedlings, outperforming commonly available commercial PGM in the market.

Key words: Nutrient uptake, Plant growth media, Zeolite, Zeoponic.

INTRODUCTION

Plant growth media (PGM) are vital materials for supporting plant growth (Gruda *et al*., 2013). PGM have physical and chemical characteristics that play a significant role in plant growth and development. Physical properties like bulk density, air space, water-holding capacity and total porosity assess the arrangement of solid, water and air components. Meanwhile, chemical properties, such as pH, nutrient content and electrical conductivity (EC), also play a crucial role in supporting plant growth (Kennard *et al*., 2020).

The quality of PGM can have a significant impact on the availability of nutrients for plants. Therefore, it is important to selecting high-quality PGM that provide the necessary nutrients and support for plant growth and development (Thakur *et al.,* 2020). The use of poor-quality PGM can result in reduced plant growth and yield, as well as decreased nutrient uptake by plants. The characteristics of poor-quality PGM include high electrical EC values, which can indicate high levels of salts that can negatively affect plant growth and development (Subandi *et al*., 2015). Hydroponics is a method of growing plants without soil, where plants are grown in a nutrient solution with or without a soilless substrate to provide physical support (Niu *et al*., 2022). Generally, PGM in hydroponics are replaced by replacement media such as rockwool, chaff charcoal, zeolite and various other light and sterile media. Hydroponic PGM must meet several criteria in order to support plant growth well. These criteria do not affect nutritional content, do not clog up the water system and have good pores (Jan *et al*., 2020).

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Zeoponic is a PGM made from zeolite mixed with other materials such as compost, cocopeat and fertilizer (Suwardi and Pangestu, 2004). Zeolite has high cation exchange capacity (CEC), ranging from 80 to 180 meq/100 g, allows for beneficial cation absorption and exchange, promoting plant growth (Suwardi *et al*., 2004). In addition, use of alternative growing media, such as compost can be used to improve soil structure, water-holding capacity and nutrient availability for plant growth (Grigatti *et al*., 2007). Cocopeat is also an organic material derived from coconut skin, making it an environmentally friendly choice for PGM. It provides

good water resistance and also provides drainage, which can help improve soil structure and availability of nutrients for PGM (Kaushal and Kumari, 2020). Furthermore, as noted by Monica (2023), agricultural waste bio-adsorbents like coconut husk have high adsorption capacities and are readily abundant.

Horticultural crops which include vegetables, ornamental and plantation are essential in agriculture (Ali *et al*., 2023). These crops require specific growing conditions, including proper soil, water and sunlight, as well as pest and disease control, to ensure healthy and high-yielding plants. As each plant species has specific nutritional requirements, farmers continuously seek new combinations of PGM (Febriani *et al*., 2021). Evaluating PGM based on their physical and chemical properties is crucial to ensuring they provide optimal conditions for diverse plant growth. Zeoponic have chemical and physical properties that are suitable for the development of plant roots (Suwardi *et al*., 2023). Forestry seedlings are young trees grown for commercial or conservation purposes. They are typically grown in nurseries and then transplanted to their permanent location once they have reached a suitable size. Forestry seedlings are important for reforestation, timber production, as well as for ecosystem services such as carbon sequestration and biodiversity conservation (Grossnickle and MacDonald, 2018).

The aim of this study is to compare the physical and chemical properties of zeoponic and commercial PGM and assess the potential of zeoponic as a PGM for various plant types, including horticulture crops and seedlings of plantation.

MATERIALS AND METHODS

This study, was involved a field experiment at the Cikabayan Education greenhouse, then conducted physical and chemical property analyses of various PGM at the Laboratory of the Department of Soil Science and Land Resources, Faculty of Agriculture, IPB University. The experiment was carried out from September 2021 to March 2022.

A completely randomized design was employed to assess the effects of different PGM on the growth and productivity of three plant species: *Solanum lycopersicum*, *Aglaonema* sp and *Swietenia mahagoni*. The study utilized five different PGM, including commercially available PGM 1, PGM 2, PGM 3 and PGM 4, commonly used in Bogor, Indonesia as well as Zeoponic.

Composition of PGM

The composition of the different PGM used in the study is presented in (Table 1). Zeoponic is formulated by combining zeolite, compost and cocopeat in a 2:1:1 ratio (zeolite: compost:cocopeat). Zeolite grains with a 5 mm diameter are thoroughly mixed with compost and cocopeat using a shovel, trowel, or by hand to achieve an even distribution. The zeoponic mixture is supplemented with NPK fertilizer 16-16-16 at a rate of 1.5 g L^{-1} and compound fertilizer is applied following the recommended dosage on the fertilizer packaging. Finally, all the ingredients are mixed to ensure a uniform distribution of the fertilizer within the zeoponic mixture (Fig 1).

Laboratory analysis of PGM

Before planting, the laboratory analysis of PGM included assessing bulk density, pH, EC, NH_4-N, NO_3-N, Available-P, C-organic, Exch-K, Exch-Na, Exch-Ca, Exch-Mg, base saturation, CEC, Fe, Mn, Cu and Zn. Methods included measuring bulk density by comparing weights per volume, pH with a 1:5 water ratio and a pH meter, EC with a 1:5 water ratio and an EC meter, NH_4-N and NO_3-N using the Kjeldahl method, Available-P with the P-Bray 1 method and vanado molybdat extraction, C-organic with the Walkley and Black method and Exch-K, Exch-Na, Exch-Ca, Exch-Mg, CEC and base saturation using the NH_4OAc 1 M pH 7.0 method. Additionally, Fe, Cu, Mn and Zn were measured using the diethylenetriaminepentaacetic acid (DTPA) extraction method.

Measurement and observation of plant growth parameters

To assess plant growth, various parameters were measured and observed, including plant height, stem diameter, number of leaves, leaf width and leaf length. Plant height was measured in centimeters from the media surface to the tip of the highest leaf, using a ruler. Stem diameter was determined with a digital caliper. The number of leaves was counted by observing fully opened leaves, while leaf width and length were measured in centimeters using a ruler on selected leaves.

RESULTS AND DISCUSSION

Chemical and physical properties of zeoponic compared to commercial PGM

All PGMs showed the pH values ranging from 6.70 to 7.78, which fall in the slightly acidic to slightly alkaline range. The optimal pH range for plant growth is from 6.0 to 7.0, which is slightly acidic to neutral (Boeckmann, 2022). The specific composition in each PGM can impact its pH. Different materials, such as zeolite, compost, cocopeat and others, have varying pH levels. Zeoponic, utilizing zeolite, helps

Table 1: The types and composition of different PGM used in the study.

Type of PGM	Composition
Zeoponic	Zeolite+Compost+Cocopeat+NPK 1.5 g L^{-1}+ Micro compound fertilizer.
PGM 1	Soil+Cocopeat + Roasted husk+Manure+Fern root.
PGM 2	Soil+Cocopeat+Compost+Manure+Roasted husk +Microorganism.
PGM 3	Teak leaves+Cocopeat+Roasted husk+Chicken manure
PGM 4	Soil+Manure+Roasted husk+Cocopeat+Bamboo leave+Microorganism.

maintain a neutral pH due to zeolite's ability to balance pH (Pangestu *et al*., 2004). Soil pH directly influences nutrient availability, affecting phosphorus (P) absorption (Barrow and Hartemink, 2023). According to (Table 2), there is a notable decrease in Available-P with increasing pH.

Phosphorus is one of the essential elements for plant growth and it's the second most crucial nutrient after nitrogen that can limit crop growth. Generally, higher available-P values generally enhance plant growth and yield, while lower values limit growth (Bai *et al*., 2013). Zeoponic media reported an available-P value of about 903 ppm (Lestari, 2022) The application of zeolite and organic fertilizer during the initial planting increase available-P levels, with zeolite enhancing P availability alongside the residual effects of organic fertilizer (Estiaty *et al*., 2005).

The high C-organic value in the PGM is due to the use of organic materials such as compost, animal manure and cocopeat in the production of PGM. C-organic is crucial for improving nutrient availability and soil texture in agricultural practices (Darusman *et al*., 2018). The addition of zeolite together with animal manure fertilizer contributes to better growth and production (Estiaty *et al*., 2005).

Zeoponic has the lowest EC value because it has a high CEC (Tjahyandari *et al*., 2023). CEC is the soil's ability to retain positively charged ions like nutrients. A higher CEC, as in zeoponic, means better nutrient retention, resulting in a lower EC value. On the other hand, PGM 2 has the highest EC value compared to other PGMs, high EC in PGM can be caused by excessive levels of nutrients or salts, which can lead to stunted growth, leaf damage and eventually plant death. Additionally, organic wastes and composts commonly contain high salt content, which can result in elevated nutrient levels and potential toxicity to plants (Ostos *et al*., 2008).

Generally, there is a positive correlation between EC and the concentration of NO_3-N (Baldi *et al*., 2020). However, in (Table 2), there doesn't appear to be a consistent correlation between EC and NO_3-N in PGM. This inconsistency can be influenced by the presence of organic matter in the PGM, which acts as a reservoir for nutrients, including NO_3-N, slowly releasing it over time. As nutrient concentrations for NH_4^+, NO_3^- and P also affect the EC levels (Wiser and Blom, 2016). PGM with higher organic matter content can have higher levels of stored NO_3-N, even with lower EC values. Additionally, different PGM may utilize different N sources, such as organic or inorganic fertilizers, which can independently affect NO_3-N levels regardless of EC. For instance, organic fertilizers release N gradually,



(a) (b) (c)

(a) mined zeolite blocks, (b) zeolite, compost and cocopeat blend, (c) zeoponic as a plant growth media.

Fig 1: Key components for zeoponic PGM production.

Table 2: Comparison of pH, EC and nutrient levels in different PGM.

Type of PGM	pH	Available-P (ppm)	C-organic (%)	EC (dS m^{-1})	NH_4-N (ppm)	NO_3-N (ppm)
Zeoponic	6.71	903	9.15	1.82	297	2015
PGM 1	7.52	743	21.49	1.61	68	977
PGM 2	7.78	777	19.90	6.17	308	1443
PGM 3	7.33	462	11.14	1.36	54	713
PGM 4	6.70	917	17.11	3.86	216	1581

Table 3: The results of analysis of bulk density, CEC, exchangeable cations and base saturation in five different types of PGM.

Type of PGM	Bulk density (g cm^{-3})	CEC	Exch-K	Exch-Na	Exch-Ca	Exch-Mg	Base saturation (%)
		(cmol(+) kg^{-1})					
Zeoponic	0.37	83.21	19.04	28.91	29.38	10.69	106
PGM 1	0.52	49.21	10.47	4.71	41.07	10.45	136
PGM 2	0.54	79.08	25.07	19.81	26.81	10.25	104
PGM 3	0.53	45.54	2.54	1.29	36.50	4.56	99
PGM 4	0.43	74.16	14.6	8.35	29.59	15.85	92

while inorganic fertilizers provide N in a readily available form.

The N source for uptake in plants is mainly in the form of NH_4^+ and NO_3^- (Feng *et al*., 2020). The ideal NH_4^+ and NO_3^- values in PGM depend on the plant species. In this study, the plant used were tomatoes, mahogany and *Aglaonema* were used. According to (Liu *et al*., 2017) research, the recommended concentration of NH_4^+ in PGM for tomato plants is typically in the range of 10-30 ppm, while the recommended concentration of NO_3^- is around 100-150 ppm. The levels of NH_4^+ and NO_3^- in the zeoponic are quite high compared to the recommended values. However, in the zeoponic contain zeolite that has the size of a cavity according to the size of the NH_4^+, so that can absorb NH_4^+. The NH_4^+ that zeolite absorbs are not immediately released into the soil solution as long as the amount of NH_4^+ in the soil is still high (Suwardi, 2009).

The analysis of physical properties was conducted on the bulk density of five different PGM revealed that they ranged from 0.37 to 0.54 g cm^{-3}, indicating a low bulk density category. Zeoponic has the lowest bulk density, indicating a less compact structure with more pore space, facilitating water flow and root penetration. In contrast, higher bulk density in other PGM may negatively impact soil physical properties and nutrient uptake (Nyéki *et al*., 2017). Therefore, the bulk density of PGM is an important parameter to consider when selecting a PGM for specific plants.

The CEC values, ranging from 45.54 cmol(+) kg^{-1} to 83.21 cmol(+) kg^{-1}, play a crucial role in determining a soil nutrient-holding capacity. A higher CEC value enhanced nutrient retention and gradual release, reducing the need for frequent fertilization. CEC and exchangeable cations exhibit a positive correlation, as CEC represents the total amount of exchangeable cations a soil can adsorb (Solly *et al*., 2020). According to the (Table 3), we can observe that zeoponic has the highest CEC value of 83.21 cmol(+) kg^{-1}, which is accompanied by relatively higher concentrations of exchangeable cations such as potassium (Exch-K), sodium (Exch-Na), calcium (Exch-Ca) and magnesium (Exch-Mg). In contrast, PGM 3 has the lowest CEC value of 45.54 cmol (+) kg^{-1}, resulting in lower concentrations of exchangeable cations.

Base saturation is the sum of base cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) held onto the soil exchange sites divided by the total CEC and expressed as a percentage (Mason and Zanner, 2005). Higher concentrations of exchangeable base cations lead to a greater base saturation percentage (Zhang *et al*., 2023). In (Table 3), zeoponic show the highest base saturation value of 106%, reflecting its elevated concentrations of exchangeable cations (Exch-K, Exch-Na, Exch-Ca, Exch-Mg). On the other hand, PGM 3 has a lower base saturation value of 99%, indicating comparatively lower concentrations of exchangeable cations.

Micronutrients, including Fe, Mn, Cu and Zn are vital for plant growth (Gomes *et al*., 2021). The data in (Table 4) show that the concentrations of these micronutrients vary widely among the different types of PGM. Referring to nutrient sufficiency standards by (Jones, Wolf and Mills, 1991), zeoponic generally provides a balanced range of essential micronutrients for tomatoes, *Aglaonema* sp. and mahagony seedlings. PGM 1 and PGM 4 exceed recommended ranges for all elements, PGM 2 meets standards for Fe and Cu but has lower Mn and Zn levels and PGM 3 meets Cu standards but has lower Fe, Mn and Zn levels.

Zeoponic for PGM of horticulture crops

Based on all observed parameters, tomato plants with zeoponic are best compared to tomato plants in other commercial PGM. Table 5 shows the height of tomato plants in the zeoponic is very different from that of other PGM, followed by the number of leaves, leaf width, leaf length

Table 4: Essential micronutrient content (Fe, Mn, Cu, Zn) in different types of PGM.

Type of PGM	Fe	Mn	Cu	Zn
	(ppm)			
Zeoponic	366	291	385	51
PGM 1	1360	478	309	492
PGM 2	371	293	384	57
PGM 3	364	291	385	50
PGM 4	281	281	281	295

Table 5: Comparison of plant growth parameters for different types of PGMs in tomato (*Solanum lycopersicum*) at 4 weeks after planting (WAP).

Type of PGM	Plant height (cm)	Number of leaves	Leaf width (cm)	Leaf length (cm)	Stem diameter (mm)
Zeoponic	47.8^a	12.0^a	11.2^a	8.1^a	7.10^a
PGM 1	10.2^c	4.0^c	3.7^b	1.9^b	2.08^d
PGM 2	9.9^c	5.0^c	3.5^b	1.6^b	2.09^d
PGM 3	17.2^{bc}	8.0^b	5.2^b	2.7^b	3.39^c
PGM 4	21.2^b	9.0^b	5.6^b	3.5^b	4.21^b

Note: Statistical significance ($P<0.05$) denoted by different letters in the same column for each plant.

Table 6: Comparative analysis of growth parameters in *Aglaonema* sp. using different types of PGMs at 13 weeks after planting (WAP).

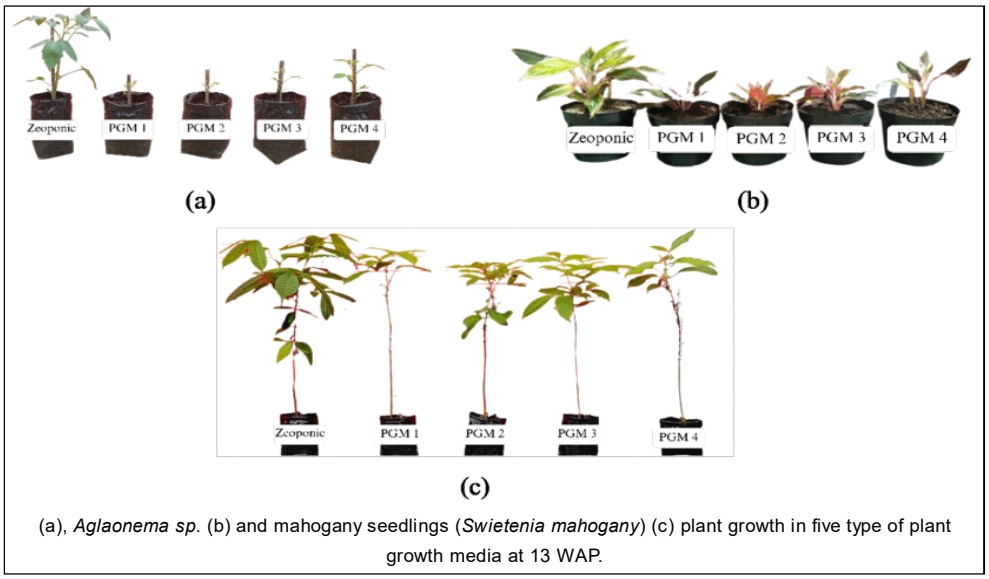
Type of PGM	Plant height (cm)	Number of leaves	Leaf width (cm)	Leaf length (cm)	Stem diameter (mm)
Zeoponic	31[a]	12[a]	6[a]	17[a]	19[a]
PGM 1	26[a]	10[a]	5[a]	15[a]	21[a]
PGM 2	26[a]	9[a]	5[a]	15[a]	17[a]
PGM 3	23[a]	11[a]	5[a]	14[a]	18[a]
PGM 4	27[a]	8[a]	5[a]	14[a]	17[a]

Note: Statistical significance (P<0.05) denoted by different letters in the same column for each plant.

Table 7: Plant growth parameters in mahogany seedlings (*Swietenia mahogany*) using different types of PGM at 13 weeks after planting (WAP).

Type of PGM	Plant height (cm)	Number of leaves	Leaf width (cm)	Leaf length (cm)	Stem diameter (mm)
Zeoponic	87.87[a]	51[a]	5.90[a]	19.20[ab]	7.13[a]
PGM 1	77.77[a]	36[ab]	5.13[a]	15.87[a]	6.28[a]
PGM 2	80.53[a]	38[ab]	4.23[a]	12.70[ab]	5.75[b]
PGM 3	75.47[a]	38[ab]	5.23[a]	15.00[b]	5.83[ab]
PGM 4	80.47[a]	29[b]	5.10[a]	15.33[ab]	6.66[ab]

Note: Statistical significance (P<0.05) denoted by different letters in the same column for each plant.



(a), *Aglaonema sp.* (b) and mahogany seedlings (*Swietenia mahogany*) (c) plant growth in five type of plant growth media at 13 WAP.

Fig 2: Comparison of tomato (*Solanum lycopersicum*).

and stem diameter. Zeoponic treatment produced plants with the most significant growth, which included the upper part of the plant and the roots of the plants (Suwardi *et al*., 2023). Roots of the tomato plant in zeoponic are also the longest in size compared to other commercial PGM (Fatiha, 2022).

Horticultural crops need NPK nutrients in order to grow and thrive. Based on the physical and chemical properties data, zeoponic has good NPK content to support the growth of horticultural crops. According to Tavallali *et al*. (2018) tomato plants need a significant amount of N to grow and thrive. N is an essential nutrient for plant growth and is required for the production of chlorophyll, which is necessary for photosynthesis. Zeoponic increased the efficiency of nutrient uptake, especially N, due to its great capacity for CEC to absorb NH_4^+. According to Grunert *et al*. (2019) tomatoes have the ability to absorb N in the form of NH_4^+ and NO_3^-. Additionally, tomato plants have been observed to exert an influence on, or even modulate, the nitrification activity that occurs in the rhizosphere.

Plants grown in soilless culture system have been found to have higher growth rates, increased yields and better quality compared to those grown in traditional soil-based systems (Gruda, 2022). Furthermore, soilless cultivation allows plants to thrive in diverse environments, making it adaptable for both outdoor and indoor settings (Suresh *et al*., 2023). Replacing soil with alternative growing mediums, especially for vegetable crops like cucumbers, peppers and tomatoes, facilitates better control over plant nutrition and eliminates soil-borne diseases (Rahil *et al*., 2020).

In Table 6, it can be seen that the *Aglaonema* sp. plants grown in zeoponic have the highest values for all growth parameters except for stem diameter. This indicates that zeoponic is highly effective in promoting the growth of *Aglaonema* sp. Furthermore, in the cultivation of ornamental plants, aesthetic value is a key indicator of quality, as stated by Adaniyah (2022). Therefore, the aesthetic value of *Aglaonema* sp. plants is highly valued in the ornamental plant industry and growers can command a premium price for plants with amazing colours. The aesthetic value of *Aglaonema* plants is rare due to their colour and leaf pattern. *Aglaonema* sp. with red-dominated colours can make amazing colours. The red colour of the leaf occurs due to the presence of anthocyanin. According to Pratama and Nihayati (2021), the use of compost may increase the anthocyanin content in plants. Therefore, using compost in zeoponic may be a way to improve the red coloration in *Aglaonema* sp. plants and increase their ornamental value. In addition, using zeoponic with greenish-grey zeolite can enhance the beauty of *Aglaonema* sp. plants in pots, while also promoting their growth and health (Suwardi and Pangestu, 2004).

Several studies have similar findings that the composition of the growth medium significantly affects the growth and quality of *Aglaonema* plants. (Widjaja *et al*., 2023) found *Aglaonema siam aurora* to be preferred in ttreatment ZA3, which consists of zeoponic mixed with NPK 16-16-16 at 0.375 g/l and micro compound fertilizer at 0.5 mg/l. The utilization of ZA3 media is resulting to the improved visibility of *Aglaonema s*p. leaf color contrast between green and red. Furthermore, in *Aglaonema*, ZA3 had the greatest plant height, number of leaves, leaf length, leaf width and stem diameter measurements. The composition of the growth medium greatly affects the growth and quality of ornamental plants and each type of ornamental plant has specific requirements for suitable growth media. Although the statistical analysis in Table 6 may not show significant differences, the data indicates that zeoponic yields higher measurements compared to other PGMs.

Zeoponic for PGM of seedling plantation

Mahogany plant seeds' growth parameters include plant height, number of leaves, leaf length, leaf width and stem diameter. Based on observations of these growth parameters, it appears that mahogany seeds exhibit the most significant growth when cultivated in zeoponic medium. This finding is supported by visual assessments, as shown in Fig 2, which indicate that mahogany seeds grown in zeoponic are taller than those grown in other commercial media. To measure plant height, the distance is taken from the base of the plant to the top of the highest leaf (Palupiningtyas, 2023). The measured growth parameter results are presented in Table 7. The result showed that zeoponic consistently yielded higher measurements in plant height and leaf width compared to other PGMs, although the differences were not statistically significant. However, significant differences were observed in number of leaves, leaf length and stem diameter, where zeoponic-produced seedlings exhibited significantly higher values compared to the other PGMs used in the study.

Mahogany seedlings require complete nutrients, such as NPK, as well as micro-nutrients such as Fe, Mn, Zn, Cu and B. The availability of sufficient nutrients in PGM is crucial for the growth and development of mahogany seedlings. The lack of certain nutrients can slow down seedling growth and cause nutrient deficiencies in plants. Zeoponic can increase the efficiency of nutrient uptake, especially N, due to its great capacity for CEC to absorb NH_4^+. The chemical and physical properties of zeoponic are responsible for the better growth of mahogany plant seedlings (Suwardi *et al*., 2023). Furthermore, the application of zeolite had a positive impact on certain soil properties, such as N, P and exchangeable K, which helped in speeding up the soil recovery process (Martelletti *et al*., 2019). A study conducted by (Špulák and Hacurová, 2021) found that the addition of clinoptilolite (mineral that belongs to the zeolite group) had a positive effect on the growth of forestry seedlings.

CONCLUSION

Zeoponic proves its superiority as a PGM based on several advantageous physical and chemical properties, such as low bulk density, moderate EC, neutral pH, high NO_3-N concentration, available-P content, moderate c-organic content and high base saturation level. Compared to commercial PGM, zeoponic significantly enhances plant height, stem diameter and leaf area across various plant species, including tomatoes, *Aglaonema* sp and mahogany seedlings. Therefore, it can be inferred that zeoponic is the best PGM compared to others commercial PGM available in the market, indicating its potential to revolutionize plant cultivation.

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Conflict of interest

All authors declare that they have no conflict of interest.

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