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Research Article

The influence of nutrient concentration and hydroponic growing media on the growth and yield of pagoda mustard greens (*Brassica narinosa* L.)

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ABSTRACT

Production of pagoda mustard greens is currently still limited, while market demand is increasing. For this reason, it is necessary to increase the yield of pagoda mustard plants through hydroponic with optimization of nutrition and media. This study aimed to determine the plant responses to the application of AB Mix nutrient concentration and growing media types, as well as the effects of their interaction on the growth and yield of pagoda mustard greens. The research was conducted in June-July 2022 at a Screen House in Ciwidey, Bandung, at an altitude of 1,200 meters above sea level. The research used a factorial completely randomized design (CRD) with three replications. The first factor was the concentration of AB Mix nutrients 1,050; 1,150; and 1,250 ppm, and the second factor was the growing media rockwool, cocopeat, sponge, and rice husk charcoal. Data were analyzed using ANOVA and further tested using the Least Significant Difference (LSD) at the 5% level. The results showed that AB Mix nutrient with a concentration of 1,250 ppm or rockwool planting media was able to increase the growth and yield of pagoda mustard greens, but there was no interaction between the two treatment factors.

Keywords: *AB Mix nutrients; cocopeat; rice husk charcoal; rockwool; sponge.*

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INTRODUCTION

Pagoda mustard (*Brassica narinosa* L.) originates from China and is often referred to by another name, *Ta Ke Chai*. Pagoda mustard is characterized by its oval-shaped leaves, a deep green leaf color, and leaves that appear concave when viewed from above (Elisa, 2022). Pagoda mustard possesses unique and beautiful characteristics with its dark green color and curly leaf surface (Jayati & Susanti, 2019). According to data from BPS (2020), vegetable production in Indonesia has consistently increased year by year. In 2017, vegetable production was recorded at 627,598 tons ha^{-1}, in 2018 it reached 635,990 tons ha^{-1}, in 2019 it amounted to 652,727 tons ha^{-1}, and by 2020, vegetable production had further risen to 667,473 tons ha^{-1}. Therefore, there is an opportunity for an increased demand for pagoda mustard greens at the consumer level.

The demand for vegetables is increasing in line with the growing population and consumer preferences. It has led to the adoption of different farming methods, one of which is hydroponics (Dahlianah et al., 2020). Hydroponics is one of the latest agricultural cultivation systems because it can be implemented in various locations and can be carried out throughout the year without being restricted by seasons. Plant maintenance through hydroponics is relatively easier compared to conventional methods (Wibowo & Asriyanti, 2018).

One crucial aspect that deserves attention in hydroponic cultivation to support its success is the choice of growing media. Imran (2017) explains that a suitable growing medium is a critical requirement in the cultivation process, especially in hydroponic systems, where the growing medium determines root development. The research results showed that the addition of husk charcoal with a Liquid Organic Fertilizer concentration of 15 ml/L was able to increase the number of leaves, length of tendrils, fruit diameter, and fruit weight. Healthy plant roots are those that exist in an environment conducive to water absorption and provide adequate nutrition. Additionally, the growing medium can have an optimal pH level and drainage for the plants. Treatment with a nutrient concentration of 1250 ppm provided the best response to mustard plant growth (Tripama & Yahya, 2018).

According to Tripama and Yahya (2018) besides the growing medium as a supporting factor in hydroponics, another essential factor to consider is nutrient. Nutrient plays a role as the energy source required by plants and is a determining factor in the yield and quality of plants, especially in the case of pagoda mustard. Ainina and Aini (2018) state that the provision of nutrient solutions in hydroponic cultivation must be precise to ensure that plants receive the necessary nutrients. Sulistyowati and Nurhasanah (2021) further add that the concentration of nutrient solutions in hydroponic cultivation is one of the crucial factors to be observed. This is because each plant requires different nutrient concentration levels. The concentration of nutrient solutions indicates the concentration of substances within them. Providing nutrient solutions that are too low or too high can hinder plant growth. Treatment with a nutrient concentration of 1250 ppm provided the best response to mustard plant growth. This research aimed to determine the effect of AB Mix nutrient concentration and various types of growing media in hydroponic cultivation systems on the growth and yield of pagoda mustard.

MATERIALS AND METHODS

Experimental site

This research was conducted from June to July 2022 at a Screen House, Ciwidey, Bandung Regency at an altitude of 1,200 m above sea level (7°5'34.486 "S 107°26'31.368" E). The highest daily temperature was 35 °C and the lowest was 21 °C.

Materials

The materials used were pagoda mustard seeds, cocopeat, rice husk charcoal, sponge, rockwool, and hydroponic nutrient AB mix. AB Mix nutrient used contained N 20.7%, P 5.1%, K 24.8%, Ca 14.5%, Mg 5.1 %, S 8.9%, and micronutrients Fe 0.1%, Mn 0.05%, Cu 0.05% B 0.03% Zn 0.02%, and Mo 0.001%. The equipment utilized in the study comprises net pots, plastic cups, scissors, 100 mL and 1,000 mL measuring cups, buckets, pH meter, TDS (Total Dissolved Solids) meter, and analytical balance. Hydroponic type uses a wick system.

Research design

This research employed a factorial completely randomized design with two factors. The first factor was the nutrient concentration with three levels, namely 1,050 parts per million (ppm), 1,150 ppm, and 1,250 ppm. The second factor was the type of growing media with four levels, which are rockwool, cocopeat, sponge, and rice husk charcoal, resulting in a total of 12 treatment combinations. Each treatment combination was replicated 3 times, yielding 36 experimental units. Each experimental unit planted 3 plants so that the total sample contained 108 plants.

Cultivation method

Pagoda mustard seeds were first soaked in water to select the viable seeds (sank in the water). Subsequently, the seeds were planted in the predetermined growing media, including rockwool, cocopeat, rice husk charcoal, and sponge. The planting medium for the nursery is then moistened with water using a hand sprayer.

The preparation of hydroponic nutrient AB Mix involved dissolving formula A in a chamber labeled A and formula B in a chamber labeled B. Then, concentration was determined in ppm (parts per million) according to the treatments using a TDS (Total Dissolved Solids) meter, which resulted in nutrient concentrations of 1,050 ppm, 1,150 ppm, and 1,250 ppm.

Seedlings with three leaves, or approximately 7-10 days after sowing (DAS), were then transplanted into net pots. These net pots were subsequently placed into the wick system hydroponic. Throughout the plant maintenance process, nutrient levels and pH were regularly monitored using TDS and pH meters for all containers. Pest and disease control was carried out manually by removing pests as needed.

Harvesting was done at 30-40 days old after planting (DAP), by uprooting the plants from the net pots. Observations of agronomic characteristics include plant height (cm), number of leaves (leaves), leaf area (cm^2), fresh shoot weight per plant (g), fresh root weight (g), dry shoot weight (g), dry root weight (g), and plant productivity (tons ha^{-1}).

Data analysis

The quantitative data were analyzed using analysis of variance (ANOVA). For any significant effect on the variable, the means were further evaluated using the Least Significant Difference (LSD) test at a 5% level of significance.

RESULTS AND DISCUSSION

Based on the research results (Table 1), the treatment with AB Mix nutrient concentration at 1,250 ppm significantly produced a higher number of leaves during the 1 to 5 days after planting (DAP) period. During the initial growth stage of pagoda mustard plants, a higher nutrient concentration is needed to enhance optimal plant growth and leaf formation. One of the essential nutrients required for this process is nitrogen, which is needed in substantial quantities to support the formation of vegetative leaf organs. Pagoda mustard is known to prioritize leaf formation, making it particularly important during the vegetative phase. the vegetative phase of the plant is stimulated to grow more dominantly (Tripama & Yahya, 2018). Similarly, the results of the leaf number parameter at 3, 4, and 5 days after planting (DAP) indicate that the treatment with AB Mix nutrient concentration at 1,250 ppm has a higher number of leaves compared to concentrations of AB Mix at 1,150 ppm and 1,050 ppm.

Table 1. The average number of pagoda mustard leaves under different nutrient concentrations and growing media treatments.

Treatment	Number of leaves				
	7 DAP	14 DAP	21 DAP	28 DAP	35 DAP
Nutrient concentration (ppm)					
1,050	4.4b	7.2b	17.0b	32.2b	53.2b
1,150	4.8b	7.9b	17.5b	32.8b	53.6b
1,250	6.0a	9.9a	20.1a	35.0a	56.2a
Significance	*	*	*	*	*
Types growing of media					
Rockwool	6.3a	10.6a	20.5a	35.3a	56.5a
Cocopeat	4.9b	8.0b	18.0b	33.1b	54.0b
Sponge	4.6b	7.7b	17.3b	32.6b	53.6b
Risk husk charcoal	4.5b	7.2b	17.1b	32.3b	53.2b
Significance	*	*	*	*	*
Interaction					
Significance	ns	ns	ns	ns	ns

Note: Numbers followed by the same letter in each column are not significantly different based on the LSD test at the α = 5%; ns = not significant; * = significant α = 5%. DAP = days after planting

According to Irawati and Widodo (2017), a higher nutrient concentration provided to plants will result in a greater number of leaves, corresponding to the higher concentration of AB Mix nutrient. An increase in the number of leaves on a plant enhances the rate of photosynthesis. This increased rate of photosynthesis leads to a higher production of total carbohydrates. Consequently, the increased leaf synthesis generates more food materials.

Meanwhile, the rockwool growing media treatment produced the highest number of leaflets during the 1 to 5 days after planting (DAP) period. At 5 DAP, rockwool media was able to produce approximately 56.56 leaflets. This is because rockwool has a higher water holding capacity (WHC) compared to cocopeat, sponge, and rice husk charcoal growing media. The higher WHC enhances nutrient absorption and supply, facilitating growth, especially in leaf development. In line with Albadri et al. (2022) opinion rockwool growing media can provide optimal nutrient supply to the root zone. This occurs because rockwool can effectively retain and supply water and nutrients, and roots can easily penetrate it, leading to optimal root development during the plant's growth process.

The treatment with AB Mix nutrient concentration at 1,250 ppm significantly resulted in the tallest plant height during the 1 to 5 days after planting (DAP) period (15.85 cm) when compared to other treatments (Table 2). This suggests that the application of hydroponic nutrient concentration AB Mix can enhance plant height. The application of AB Mix concentration at 1,250 ppm is concluded to meet the nutrient requirements of the plant during the vegetative stage. This aligns with the findings of Tripama and Yahya (2018) that various nutrient concentration treatments can be used as a method to determine the suitable concentration for plant growth according to the plant's needs.

The different growing media treatments indicate that rockwool significantly resulted in a taller plant height (16.4 cm) compared to cocopeat, sponge, and rice husk charcoal media (Table 2). This is attributed to rockwool media having a substantial substrate particle content, which facilitates good porosity for nutrient absorption by the plant. Sponge growing media, on the other hand, has a lower water-holding capacity and tends to heat up. Consequently, the water availability contained in sponge media that is absorbed by the roots is lower compared to its availability in rockwool growing media (Haryoyudanto, 2018).

Table 2. The average height of pagoda mustard plants under different nutrient concentration treatments and growing media.

Treatment	Plant height (cm)				
	7 DAP	14 DAP	21 DAP	28 DAP	35 DAP
Nutrient concentration (ppm)					
1,050	4.53b	6.33b	8.17b	10.12b	13.35b
1,150	5.24b	7.06b	8.97b	10.72b	13.86b
1,250	6.65a	8.63a	10.80a	13.18a	15.85a
Significance	*	*	*	*	*
Types growing of media					
Rockwool	7.77a	9.55a	11.43a	13.34a	16.43a
Cocopeat	5.18b	6.99b	8.99b	11.02b	14.10b
Sponge	4.61b	6.72b	8.27b	10.64b	13.61b
Risk husk charcoal	4.34b	6.11b	8.11b	10.36b	13.24b
Significance	*	*	*	*	*
Interaction					
Significance	ns	ns	ns	ns	ns

* *Note:* Numbers followed by the same letter in each column are not significantly different based on the LSD test at the α = 5%; ns = not significant; * = significant α = 5%; DAP = days after planting.

The treatment with AB Mix nutrient concentration at 1,250 ppm resulted in the widest leaf area (27.7 cm^2) as compared to concentrations of 1,150 ppm and 1,050 ppm (Table 3). The increase in leaf area with the addition of nutrient concentration is believed to enhance the nutrient supply needed by the plant for optimal growth and leaf formation. Similar to the number of leaves, leaf area is also influenced by nutrients such as nitrogen contained in AB mix nutrition, which is very important for leaf formation. According to

Damanhuri et al. (2022), the provision of nitrogen can enhance protein synthesis and chlorophyll formation in leaves. An increasing leaf area indicates the leaf's ability to absorb and receive more light, resulting in higher energy and photosynthesis (Lutfiah et al. 2021). Increasing nutrient concentration can contribute to the availability of water and essential nutrients such as nitrogen, phosphorus, and potassium, which can aid in the photosynthesis process to ensure it operates optimally, thereby resulting in larger leaves (Tripama & Yahya, 2018).

Table 3. Leaf area, fresh weight of edible part, shoot and root weight, and yield of pagoda mustard plants under different nutrient concentrations and growing media.

Treatment	Leaf area (cm^2)	Fresh edible part (g)	Shoot dry weight (g)	Root weight (g)		Harvest (tons ha^{-1})
				Fresh	Dry	
Nutrient concentration (ppm)						
1,050	24.7b	68.92b	4.99b	16.0b	0.82b	13.78b
1,150	25.5b	69.83b	5.81b	16.9b	0.84b	13.91b
1,250	27.7a	71.18a	7.80a	19.1a	0.89a	14.23a
Significance	*	*	*	*	*	*
Types growing of media						
Rockwool	27.8a	72.68a	8.43a	19.2a	0.90a	14.54a
Cocopeat	25.1b	69.53b	5.66b	17.4b	0.84b	13.91b
Sponge	25.9b	68.96b	5.60b	16.6b	0.84b	13.79b
Risk husk charcoal	25.1b	68.73b	5.11b	16.1b	0.83b	13.74b
Significance	*	*	*	*	*	*
Interaction Significance	ns	ns	ns	ns	ns	ns

Note: Numbers followed by the same letter in each column are not significantly different based on the LSD test at the α = 5%; ns = not significant; * = significant α = 5%

The growing medium in terms of leaf area using rockwool resulted in larger leaves (27.8 cm^2) compared to cocopeat, sponge, and rice husk charcoal growing media. This is because rockwool has good drainage, which provides it with more substrate compared to cocopeat, rice husk charcoal, and sponge growing media. The abundance of substrate can enhance root capability to absorb water into the plant more effectively. On the other hand, sponge growing medium has lower water retention capacity, resulting in fewer substrates, which limits the roots' ability to absorb water into the plant. This confirms that rockwool can be a suitable growing medium for hydroponic cultivation of pagoda mustard.

AB Mix concentration of 1,250 ppm significantly yielded a higher fresh weight of pagoda mustard consumption compared to concentrations of 1,150 ppm and 1,050 ppm, amounting to 71.18 g per plant (Table 3). This is suspected to be due to the provision of the appropriate concentration and nutrients absorbed by the plants, facilitating effective absorption. This aligns with Rahmawati's (2018) assertion that the fresh weight of plants is influenced by the quantity of nutrients and energy during their growth. The formation of leaves, stems, and roots necessitate both micro and macronutrients.

Meanwhile, using rockwool as the growing medium led to the highest fresh weight of consumption at (72.68 g) (Table 3). In comparison to other treatments, the fresh weight of consumption only reached approximately 68-69 g per plant. This suggests that rockwool has a better water retention capacity, making it less prone to drying out and maintaining sterility. The increased water retention ability of rockwool affects the number of leaves; the more leaves there are, the higher the water content. This aligns with the findings of Meriaty et al. (2021) stating that rockwool growing media have small particles that influence water retention. The water retention capacity of a growing medium is influenced by particle size, and smaller particles lead to larger pore surface areas, which in turn enhance water retention and absorption capabilities.

Root fresh weight of mustard greens varied among the AB Mix concentration and growing media treatments (Table 3). The concentration of 1,250 ppm resulted in a higher root fresh weight (19.13 g) compared to 1,150 ppm (16.89 g), and 1,050 ppm (16 g). This is likely because the treatment of nutrient concentration can enhance the availability of micro and macronutrients to meet the plant's needs. This is supported by Kusumaningtyas et al. (2015) in their research, stating that a combination of fertilizers can increase the availability of nutrients that can be effectively absorbed by plants, promoting wider leaf growth and increased photosynthesis. The results of photosynthesis contribute to the formation of root, leaf, and stem cells, thereby influencing root fresh weight.

The rockwool growing medium tended to stimulate in heavier root fresh weight (19.21 g) compared to the cocopeat, sponge, and rice husk charcoal growing media (Table 3). This is in line with the research conducted by Agustina (2019) which found that the root fresh weight on rockwool growing media produced the best results. Rockwool has better fibrous compared to sponge or other artificial growing media, and its porosity allows it to retain water optimally for plant growth. Despite its high water-holding capacity, rockwool also releases water quickly, ensuring optimal root aeration.

Different treatments of AB mix nutrient concentration and growing media significantly affected the dry weight of the shoot (Table 3). The treatment with AB mix nutrient concentration of 1,250 ppm was significantly higher than cocopeat, sponge, and rice husk charcoal. The application of 1,250 ppm concentration had the highest average dry weight of the canopy, approximately 7.8 g. This indicates that nutrient uptake was optimal, resulting in the best growth. Dry weight represents the balance between photosynthesis and respiration. Respiration, on the other hand, leads to a decrease in dry weight because of the release of CO_2 during respiration (Djaelani et al., 2018).

Rockwool planting media stimulated a higher shoot weight (8.43 g) than the others (Table 3). This research used a wick system in hydroponics where nutrients were absorbed through flannel cloth. It is likely that rockwool media facilitates uniform texture and pores as compared to the other media leading to smoother water flow into the plants. This is in line with Warjoto et al. (2020) in their research stating that sponge planting media has a lower density than rockwool, cocopeat, and rockwool.

The average root dry weight with a concentration treatment of 1,250 ppm was significantly different from the concentration treatments of 1,150 ppm and 1,050 ppm (Table 3). The concentration treatment of AB Mix 1,250 g resulted in the highest root dry weight (0.89 g) compared to treatment of 1,050 ppm (0.82 g) and 1,150 (0.84 g). Root dry weight is influenced by root fresh weight. When the fresh weight increases, the dry weight also increases. This is because the combination of nutrient concentration treatments leads to nutrient levels that match the plant's needs, resulting in healthier roots and optimal root growth, which in turn increases root weight.

Rockwool growing media produced significantly higher root dry weight (0.9 g) compared to cocopeat (0.84 g), sponge (0.84 g), and rice husk charcoal (0.83 g) growing media (Table 3). This is likely because plants grown in rockwool growing media able to accumulate larger dry weight than the others. This aligns with Albadri et al. (2022), who stated that dry weight represents the utilization of sunlight and the absorption of nutrients in plant canopy growth.

Based on the research results, it is evident that the AB Mix nutrient concentration and the type of growing media significantly affect the plant's productivity. In this study, the treatment with a concentration of 1,250 ppm exhibited the highest productivity (14.23 tons per hectare) compared to 1,150 ppm at 13.91 tons per hectare and 1,050 ppm at 13.78 tons per hectare (Table 3). The productivity achieved in this research is significantly higher when using AB Mix fertilizer compared to previous research by Saepuloh et al. (2020), which reported a productivity of 3.99 tons per hectare using organic fertilizer. This difference can be attributed to the effective nutrient supply provided by AB Mix fertilizer for pak choi, resulting in faster nutrient absorption by the plants.

Sundari et al. (2016) stated that AB Mix contains essential elements to support plant growth and development. Moreover, Narulita et al. (2019) concluded that variations in the number of plant leaves and fresh weight can be attributed to the different nutrient concentrations. The 1,250 ppm concentration likely is the most suitable for the plants in terms of nutrient uptake and utilization for growth and development, considering factors such as nutrient availability, concentration, and pH. This aligns with Jaya's (2016) perspective that optimal plant growth depends on the availability of water, minerals, and nutrients in the growing environment.

Productivity of mustard greens using rockwool growing media was significantly higher (14.54 tons per hectare) compared to cocopeat (13.91 tons per hectare), sponge (13.79 tons per hectare), and rice husk charcoal (13.74 tons per hectare) growing media (Table 3). This is believed to be due to rockwool growing media having higher nutrient content and better nutrient retention capabilities compared to cocopeat, rice husk, and sponge growing media, resulting in greater nutrient availability. This finding aligns with the research conducted by Saroh et al. (2016), which indicated that rockwool growing media contains essential nutrients such as potassium (K) and phosphorus (P) needed by plants during photosynthesis, leading to faster growth and highest productivity.

CONCLUSIONS

AB Mix nutrient with a concentration of 1,250 ppm or rockwool planting media was able to increase the growth and yield of pagoda mustard greens. However, there was no interaction between AB Mix and rockwool planting media on such growth variables.

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