EFFECTS OF NUTRIENT SOLUTION ON GROWTH, YIELD AND AROMATIC COMPOUND OF PERSICARIA MINOR CULTIVATED USING HYDROPONICS SYSTEM

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ABSTRACT

Persicaria minor locally known as kesum from the family Polygonaceae is a common aromatic herbal plant found in Malaysia. Hydroponic cultivation of kesum using a deep water culture (DWC) system can be an alternative option for kesum growers in increasing crop yields. The deep water culture system is a method in which liquid fertiliser solution is given directly to the plant roots without any medium and water flow. Aromatic compounds such as aldehyde and caryophyllene in kesum have shown nutraceutical and pharmaceutical properties. The study's main objective was to determine the effects of nutrient solution on the growth, yield and aromatic compounds (aldehyde and caryophyllene) of kesum cultivated using a hydroponic system. Plants were grown under one of four nutrient solution regimes and the experiment was conducted under a side-netted rain shelter. The four treatments comprised 100%, 50%, 25% and 0% strength of the MARDI's nutrient concentrations typically used in commercial vegetable production. The experiment was arranged in a Randomized Complete Block Design (RCBD) with 4 replications. Plants were harvested eight weeks after planting. Plants grown supplemented with 50% strength of nutrient concentration gave the best growth performance, biomass yield and aldehyde aromatic compound compared to the other treatments. They produced the highest plant height (78 cm), fresh biomass yield (174 g per plant) and aldehyde content (aldehyde C-10: 5.80% and aldehyde C-12: 12.23%). Plants treated with 100% nutrient concentration produced the lowest aldehyde-C10 (0.75%) and aldehyde C-12 (2.11%) but the highest caryophyllene (12.53%) content compared to other treatments. However, plants treated with 0% nutrient concentrations exhibited major nutrient deficiency symptoms and died after 3 weeks of planting. Hence, it can be concluded that the kesum plants cultivated using hydroponics' deep water culture system supplemented with 50% strength of MARDI's nutrient concentrations gave the highest plant growth, biomass yields and both aldehyde C-10 and C-12 compound.

Keywords: Hydroponics, nutrient solution, yield, aldehyde, Persicaria minor

Introduction

Kesum or its scientific name *Persicaria minus* is a herbal plant that originates from Southeast Asia (Malaysia, Indonesia, Vietnam, Thailand) and thrives in moist and watery areas. Kesum leaves are also the main ingredient in cooking because of their aromatic properties that can evoke the delicious taste of food (Chan et al., 2018). In addition, kesum can be made as a decorative tree in the yard and can be used as a source of aromatherapy. Kesum is also used as medicine to overcome health problems. Kesum is rich in micronutrients, total phenolic content (TPC) and natural antioxidants. This active ingredient gives curative medicinal benefits in terms of antioxidants, anti-inflammatory, anti-ageing, improves memory and promotes the body's immune system (Musa Ahmed et al., 2015; Vimala et al., 2011). Kesum is a shrub plant that has a height of approximately 45 - 60 cm. Kesum leaves are small, long leaves (5 - 7 cm) and pointed, green in colour and have a reddish cylindrical shape stem. Kesum has short node sections and is easily rooted. It has flowers that are purple in colour. There are two types of kesum which are creeping and vertical. Both types of kesum have a fragrant aroma. For commercial cultivation, vertical types of kesum plants are suitable for facilitating farm management and leaf harvesting.

Kesum is categorized as an aromatic herbal plant with nutraceuticals, pharmaceutical and therapeutic benefits (Arasu et al., 2019, Jongrungraungchok et al., 2023). Aldehyde and caryophyllene are two aromatic compounds that are being intensively studied in *Persicaria* spp essential oil (Fujita et al., 2015). Aromatic aldehydes also give plants their fragrances and flavours including aliphatic aldehydes, analogical alcohols, as well as their sulfanyl derivatives, sesquiterpenoids (caryophyllene and its derivatives) and monoterpenoids (Fujita et al., 2015). Studies on the *Persicaria* spp essential oil revealed its antibacterial properties (Fujita et al., 2015; Wannissorn et al., 2005), hydrogen peroxide, radical scavenging activities, antifungal activity (Chan et al., 2018), and inhibition activity against pathogenic bacteria (Nanasombat and Teckchuen, 2009). Aldehydes and their derivatives will be the focus of this study with regard to their antimicrobial, antioxidative, anti-inflammatory and immunomodulatory effects.

Usually, the cultivation of kesum is done using a conventional method and is suitable for planting in mineral or peat soil that has a good irrigation system because its growth is highly dependent on soil moisture (Azmil et al., 2001). However, the conventional cultivation of kesum required a large area and labour force, especially during planting and harvesting activities. The problem of environmental pollution also occurred in the case of excessive use of fertilizers that leached into the soil and polluted the water, especially underground water. Deep water culture (DWC) or raft technique is the easiest hydroponic technique to carry out and cost-effective to manage. The deep-water culture technique is a method where liquid fertilizer is given directly to the plant roots without any medium and water flow (Yaseer Suhaimi et al., 2022). This technique is very practical for planting leafy vegetables such as mustard, kalian, kale, pak choy and herbs such as pegaga, selom, kaduk, basil, and mint including kesum. There is potential to increase the growth and yield of kesum using a hydroponic system based on the significant increase in yields of leafy and fruity vegetables grown on a hydroponic system.

Plant nutrition management in hydroponic cultivation is more effective and accurate compared to conventional soil planting (Savvas et al., 2003). Several studies have shown that nitrogen nutrition plays an essential role in fruit growth, development and production processes (Guérineau et al., 2003, Zhou et al., 2012). Nitrogen concentration in fertilizer might also influence plant secondary synthesis and metabolism (Wang et al., 2020). Previous studies have shown that nitrogen fertilizers have a significant effect on the plant's active compounds (Zhao et al., 2012). The application of nitrogen can increase patchouli essential oil compared to plants grown without nitrogen (Singh et al., 2002). However, there are certain plants' active compounds that were not influenced by nitrogen levels (Xiong et al., 2019). Thus, this study was conducted to determine the effects of nutrient solution on growth, yield and aromatic compound of *persicaria minor* cultivated using a hydroponics system. Specifically, the plant height, stem diameter, plant canopy, SPAD value, fresh and dry weight of leaves and shoots were measured. Two aromatic compounds aldehyde and caryophyllene content were also determined.

Materials and Methods

Study Area

A side-netted rain shelter 30 m long x 10 m wide x 4.5 m high located in MARDI Station Serdang, Selangor, Malaysia was used in the study. All structures were made of galvanised steel frames with transparent polyethene film (180 μm thick) roofing and insect-repellent net (0.1 x 0.1 mm^2) side cladding. Entrance into the shelter must be through double doors to reduce the chance of insect entry.

Experiment unit

The deep water culture (DWC) or raft technique was the hydroponic technique used to conduct the experiment. Hydroponic containers made of fibreglass were used in the study. The hydroponic tank size is 90 cm wide × 300 cm long × 25 cm high. Kesum plant cuttings were placed on polystyrene with a thickness of 2.5 cm and floated on the surface of the nutrient solution like a raft. The polystyrenes were tightly packed to cover the entire hydroponic container. Plant holes with a diameter of 1.6 cm with a distance of 17 cm each were made on polystyrene. Each hydroponic container was equipped with a 60-watt submersible water pump connected to a PVC pipe to provide uniform fertiliser mixing in the hydroponic container. Other equipment and materials needed are two units of 100 L fertiliser stock barrels, an EC meter to measure the fertiliser concentration and a sponge as a germination medium for the cutting.

Planting materials

Kesum plants were propagated through stem cuttings. Shoot cuttings with a length of 30 cm with 7-9 nodes were used as planting material. The leaves and side shoots on the cuttings were removed leaving only the leaves on the main shoots. Stem cuttings were clamped with a wet sponge as a germination medium was included in the planting hole on the polystyrene. The 15 cm half of the cutting was immersed in the fertiliser solution, while the other 15 cm was on the top of the polystyrene of the hydroponic container. The planting activity was done in the evening to reduce the stress on the plant material. Kesum cuttings started to root after three days.

Nutrient supplementation

The fertiliser was formulated by MARDI based on the needs of the vegetable plant (Yaseer Suhaimi et al. 2009). All the fertiliser components were water-soluble. The fertiliser stocks were prepared according to Yaseer Suhaimi et al. (2011). The macro and micro nutrients were prepared separately as A and B stock solutions respectively, at one hundred times dilution. Solution A contained calcium nitrate and iron, while solution B contained all other components. All components were added one by one to ensure that they dissolved completely in the water. In preparing stock A solution, calcium nitrate was added into the container containing tap water (pH 5.5 – 6.5) and stirred until it dissolved, then the solution was poured into a 100-litre vessel. Iron powder was added into another container that contained tap water, stirred until it dissolved completely, and then added into the vessel. The same procedure was applied in preparing stock B solution. Stock A and stock B were added into the hydroponic container at a 1:1 ratio until the needed electricity conductivity (EC) was achieved.

After the fertilizer solution were added to the hydroponic container, the submersible pump was turned on to ensure that the fertilizer solution was mixed inside the hydroponic container. The submersible pump was turned on for five minutes to ensure that the fertilizer solution was completely mixed in the hydroponic container. The concentration of the fertilizer solution was checked periodically at least once every two weeks or when the volume of the fertilizer solution in the container began to decrease due to sublimation and were used by the plants. The concentration of fertilizer solution for kesum plants were maintained at EC 2000 - 2400 μS/cm throughout the cultivation period.

Treatments and Experimental Design

The treatments were arranged in a randomised complete block design (RCBD) with four levels of treatment with four replicates and eighty plants per treatment. There were four concentrations of fertiliser strength used as treatments in this study. These treatments were as follows: The four treatments comprised T1: 0%, T2: 25%, T3: 50% and T4:100% strength of the MARDI's nutrient concentrations typically used in commercial vegetable production. Routine horticultural practices for pests and diseases were followed. Insecticide (*Malathion*) and fungicide (*Benlate*) were applied once every 2 weeks.

Parameter measurement

The growth of the kesum plants was measured eight weeks after planting by measuring plant height, stem diameter, plant canopy, fresh weight of leaves and shoot, dry weight of leaves and shoot and SPAD value. The plants were randomly selected and harvested after eight weeks of planting to determine the yield and growth of kesum. The weight was measured immediately after harvest to prevent desiccation and water loss from the leaves.

Aldehyde & Caryophyllene content analysis

After harvesting, kesum was first sun dried followed by air drying for 48 hours to remove about 40% of moisture content. The dried samples were grinded into powder and extracted using hexane for 24 hours. The extract was then filtered before being injected into a UV-spectrophotometer at 248 nm wavelength for aldehyde and caryophyllene analysis.

Statistical Analysis

Data obtained were subjected to statistical analysis using analysis of variance (ANOVA) procedures to assess the significant effect of all the variables investigated using SAS version 9.1. Means were separated using the Duncan Multiple Range Test (DMRT) as the test of significance at $p \leq 0.05$.

Results and Discussion

Effects on plant growth and biomass

Table 1 showed the results of plant growth parameters for plant height, stem diameter, plant canopy, SPAD value, and fresh and dry biomass per plant. Data indicated that there were highly significant ($p < 0.05$) differences among the nutrient concentration treatments tested. T3 or 50% strength of nutrient concentrations recorded the highest value in plant height (75 cm) compared to other concentrations tested. However, there was no significant difference in terms of plant height between treatments. The highest stem diameter was observed in T2 or 25% of nutrient concentration followed by T4 and T3. However, there was no significant difference between T3 and T4 in terms of stem diameter. There were also no significant differences in plant canopy between each treatment.

The highest SPAD values were obtained from plants supplemented with 100% nutrient concentration followed by 50% and 25% nutrient concentration respectively. However, there was no significant difference between T3 and T4 in terms of SPAD value. Studies showed that higher application of nutrient concentrations tends to increase the SPAD value. The higher nutrient concentration increased the SPAD value and kesum leaves tend to be darker green in colour. Previous studies have shown that there was a significant correlation between SPAD values and the contents of chlorophyll and nutrient concentration in plant leaves (Huang et al., 2008). Meanwhile, Sakamoto and Suzuki (2022), stated that a deficiency of nutrients resulted in lower chlorophyll in leaves, resulting in earlier plant death. Plants treated with 0% of nutrient concentration exhibited major deficiency symptoms and plants died after 3 weeks of planting. These studies showed that kesum plants needed at least 25% of nutrient concentration to grow. Suitable nitrogen concentrations showed plant growth promoting effects and were used as fertilizer (Mousavi Kouhi et al., 2014). There were significant nutrient concentration effects on the fresh and dry weight of leaves and shoots between treatments. The highest leaves and shoots per plant fresh weight were observed in T3 (174 g) followed by T2 (159 g) and T4 (152 g). The study revealed that 50% nutrient concentration strength resulted in the optimum vegetative biomass. There was a 9.4% to 14.5% increment in vegetative biomass obtained in 50% nutrient concentration strength compared to other treatments. The dry weight of leaves and shoots per plant increased proportionally with the fresh weight of leaves and shoots per plant. The highest dry weight of leaves and shoots per plant was also found to have the highest fresh weight of leaves and shoots per plant. Results revealed that plant height attributes contributed to the vegetative biomass, since higher plant height resulted in higher vegetative biomass.
Nitrogen is a known nutrient that can influence plant growth and development by affecting photosynthesis and the uptake of minerals (Santachiara et al., 2017, Wu et al., 2019). Application of nitrogen at the rate of 80 – 100 kg/ha had increased kesum yield

compared to 180 – 200 kg/ha in conventional soil planting (Azmil et al., 2001). Nitrogen fertilizer significantly increased the plant biomass, height, canopy and SPAD value as shown in the study (Wang et al., 2020). Previous reports showed that hydroponically grown plants have different growth characteristics compared with soil grown plants (Manzocco et al., 2011). The responsiveness level of hydroponically grown plants to nutrient concentration might be different from soil grown plants (Miller et al., 1989). Nitrogen promotes the number of meristematic cells and their growth leading to the formation of biomass. Furthermore, N application is known to increase the levels of cytokinin, which affects cell wall extensibility (Lawlor, 2002; Bloom et al., 2006).

Table 1. Effects of nutrient solution strength on plant growth after two months of cultivation

Treatment	**Plant height (cm)**	**Stem diameter (mm)**	**Plant canopy (cm)**	**SPAD value**	**Fresh weight of leaves and shoots per plant (g)**	**Dry weight of leaves and shoots per plant (g)**
T1: 0%	nil	nil	nil	nil	nil	Nil
T2: 25%	75[a]	7.2[a]	51[a]	44[b]	159[b]	35.9[b]
T3: 50%	78[ab]	6.3[b]	52[a]	48[a]	174[a]	40.5[a]
T4: 100%	74[a]	6.5[b]	56[a]	52[a]	152[c]	31.3[b]

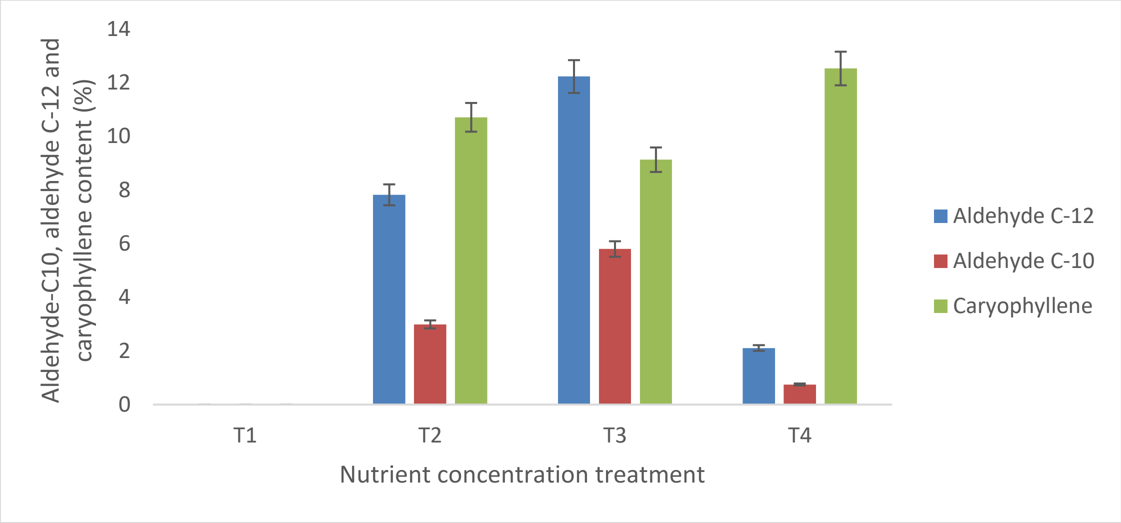
Mean values in the same column followed by the same letter are not significantly different at $p < 0.05$

Effects on aromatic content

The positive effects of nutrient concentration in plants have been widely studied, on the morphological and physiological characteristics. Nutrient concentration affected the growth, yield, fruit quality, and chemical composition of plants (Tabatabaei et al., 2006). Essential oil derived from the leaves of *P. minor* has been reported to contain aldehydes and caryophyllene that give the plant its aromatic properties (Baharum et al., 2010). There were significant nutrient concentration effects on aldehyde-C10, aldehyde C-12 and caryophyllene content (%) content between treatments (Figure 1). Plants treated with T3 or 50% nutrient concentration showed the highest aldehyde-C10 (5.80%) and aldehyde C-12 (12.23%) content but content lowest caryophyllene (9.13%) among treatments. Plants treated with T4 or 100% nutrient concentration produced the lowest aldehyde-C10 (0.75%), aldehyde C-12 (2.11%) and highest caryophyllene (12.53%) content compared to other treatments. Data revealed that plants supplemented with 50% nutrient concentration strength raised the highest vegetative biomass, aldehyde C-10 and C-12. However, plants supplemented with 100% nutrient concentration strength gave rise to the lowest vegetative biomass with higher caryophyllene content.

There is a trend between aldehyde and caryophyllene where a high content of aldehyde in the plant sample lowered caryophyllene content and vice versa. Similar studies on *Kickxia aegyptiaca* essential oil revealed the same pattern linking aldehyde and caryophyllene trends, where high aldehyde with lower caryophyllene content (Abd-ElGawad et al., 2022). Optimal nitrogen concentration application rate can increase the yield and active ingredients of *A. mongolica* (Wang et al., 2020). Previous studies revealed that increased nutrient concentration can enhance strawberry, cucumber, lettuce, tomato, melon productivity and quality parameters in soilless conditions (Asao et al., 2013; Sapkota et al., 2019; Conesa et al., 2008; Fallovo et al., 2009; Nakro et al., 2023). Generally, nitrogen applications increase oil content and yield in aromatic plants by stimulating biomass, leaf area development and photosynthetic rate level (Sangwan et al., 2001). The results of the present study are also supported by the findings of Daneshian et al. (2009) and Azizi et al. (2009) on plants other than *P. minor*.

Figure 1: Effects of nutrient solution strength on aldehyde C-10, aldehyde C-12 and caryophyllene contents in plants after two months of cultivation



Conclusion

Studies revealed that *Persicaria Minor* plants respond very well to 25% – 100% nutrient concentration strength. The plant was able to grow and produce vegetative biomass when supplemented with nutrient concentrations ranging between 25% – 100% strength. Plants supplemented with 50% strength of nutrient concentration gave the best plant growth performance based on vegetative growth and high aldehyde C-10 and aldehyde C-12 content. Meanwhile, the best nutrient concentration to obtain the highest caryophyllene contents was 100% strength of nutrient concentration. Thus, it can be concluded that for plant growth, biomass yield and aldehyde content, the nutrient concentration at 50% strength is the efficiency rate of application for *Persicaria Minor* grown using a hydroponic system. However, 100% strength of nutrient concentration can be considered to obtain high caryophyllene content.

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