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The Effect of Soilless Media and Foliar Application on the Growth and Yield of *Solanum Lycopersicum*

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Tomato crop production is currently threatened by a calcium deficient disease called blossom-end rot. To enhance the nutrient intake in the tomato plant, this research explores the potential of soilless media through the enhancement of cation exchange capacity (CEC) and the direct intake of calcium through a foliar application. Zeolite and rice husk ash (RHA) have great potential to enhance the CEC of a media. The foliar method is applied to ensure that the fruits have a sufficient amount of calcium to combat blossom-end rot. The aims of this research are to determine the effect of different soilless media formulation on plant growth and yield of tomatoes (*Solanum lycopersicum*), and also to determine whether the foliar application can help prevent blossom-end rot disease. Different ratio media formulations of coco peat mixed with zeolite (Z5, Z10, and Z15) and coco peat mixed with RHA (R30, R50, and R100) were evaluated and compared with 100 % coco peat as control. The foliar was applied using 50 ppm chitosan in liquid form for tomatoes planted using the R30 and R50 media. After transplantation, they were sprayed once a week starting from Week 4 until Week 10. Each type of media formulation and a foliar application was planted with 10 tomato plants that were supplied with 1.9 dS/m nutrient solutions. The experiment was conducted for 10 weeks, where the pH of the media, the height of plants, and the weight of fruits were measured weekly. Based on the results, the pH for all media formulations was consistent within the range of pH 5.5 – pH 6.8. The highest marketable yield, 1,628.5 g, was produced by R50 with a size greater than 24 mm. Comparing the RHA and zeolite medium a total of 3,456.0 g of fruits was produced using RHA and 3,209.4 g of fruits using zeolite, making RHA the most suitable soilless media for growing tomatoes. The observation between plant growth with and without foliar chitosan demonstrated that chitosan effectively controls blossom-end rot disease in the tomato plant.

1. Introduction

In Malaysia, tomato has large scale cultivation area currently operating in Cameron Highlands. The high marketable yield of tomatoes is based on the quality of the fruit that is free from diseases and meets the standard market size. This has led to the utilization of soilless culture systems using non-soil materials and agro-wastes to enhance the nutrient content and plant growth. The utilization of these medium mixtures is considered environmentally sustainable and has attracted interest among researchers. Unfortunately, the production of tomatoes is being threatened by a common nutrient deficient disease called blossom-end rot. This is one of the major diseases for tomatoes that are caused by deficient calcium levels in the fruit resulting in a flattened black spot on the tip end of the tomato fruit, as shown in Figure 1.

The productivity of vegetables or plants depends highly on the media or soil conditions. It is an important aspect of growing vegetables and plants as it determines the soil productivity where the major nutrient uptake takes place from the soil absorbed by the root, and subsequently distributed throughout the plant, affecting the fruits, pH, and cation exchange capacity.

CEC is among the factors that affect soil productivity. Soil pH refers to the acidity or alkalinity of the soil. The suitable range for the soil pH of tomato plants is between a pH of 5.5 to a pH of 6.8 (Soil Analysis 101, 2014).

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Soil CEC is a measure of the quantity of negatively charged sites on soil surfaces that can retain positively charged ions (cations) such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^{+}), by electrostatic forces (Ross and Ketterings, 1995). The binding of soil particles and cation nutrients is important because it will prevent the nutrients from leaching. The cation exchange sites can be found primarily on clay minerals and organic matter surfaces. Soil organic matter will develop a greater CEC at a near-neutral pH than under acidic conditions (Ross and Ketterings, 1995).

Figure 1: Blossom-end rot tomatoes

In recent research by Gondek et al. (2019), it was found that the CEC of soil increased when biochar was introduced into the soil. Research by Rusli et al. (2018) concluded that RHA promotes maintaining the pH level of a media by acting as a buffer, as well as increasing the uptake of nutrients, and improving the strength of the medium. Shamsuddin et al. (2020) applied zeolite mixed with coco peat as the media to enhance the nutrient uptake for tomatoes. Zeolite has a high cation exchange capacity and large porosity which will allow the capture of excessive nutrients.
Chitosan, on the other hand, has proven to have anti-microbial properties that can control the anthracnose disease (Jitareerat et al., 2017). The foliar application is one of the more effective methods to ensure that nutrients can be supplied directly onto specific parts of the plant such as flowers or fruits.
In this research, the objectives are 1) to determine the effect of different soilless media formulation of zeolite and RHA on the plant growth and yield of tomato, and 2) to seek the potential usage of chitosan as foliar to effectively prevent blossom-end rot disease on tomatoes.

2. Experimental setup

The experiment was done in two stages; the first stage is the investigation of what would constitute the best medium (Table 1), and the second stage is the evaluation of the potential usage of chitosan as foliar. The second stage of the experiment was conducted using the best medium that was obtained during first stage of the experiment (Table 2).

2.1 Medium preparation

The medium mixtures were prepared according to the volume percentage, as presented in Table 1. During the first stage of the experiment, each medium was planted with 10 plants, with a total of 70 plants observed for 10 weeks. Foliar was applied during the second stage of the experiment. The medium was prepared similarly to the R30 and R50 medium during the first stage, as presented in Table 2. During the second stage of the experiment, 10 plants were tested for each medium (40 plants in total) for 10 weeks.

Table 1: Volume percentage of zeolite and RHA mixed with coco peat for medium preparation

Media type	Label	Volume % of media (vol%)	Volume % of coco peat (vol%)
Zeolite	Z5	5	95
	Z10	10	90
	Z15	15	85
Rice Husk Ash	R30	30	70
	R50	50	50
	R100	100	0
Blank	C	0	100

Table 2: Medium preparation for chitosan application

Medium Label	Chitosan concentration (ppm)	Volume % of RHS (vol%)	Volume % of coco peat (vol%)
R_130	-	30	70
R_150	-	50	50
R_230	50	30	70
R_250	50	50	50

2.2 Fertigation setup

The fertigation system was used as the irrigation system to supply consistent nutrients to all the plants. The fertigation system consists of a 2,000 L storing capacity nutrient tank, an operation timer, and a 30 W pump. The nutrient solution from the tank was pumped out through a 16 mm low-density polyethylene (LDPE) pipe which was then connected to a 1 mm capillary tube and dripped down to the plant root through a dripper.

2.3 Tomato planting and irrigation scheduling

The tomato seeds were sowed in a sowing tray that was filled with peat moss. The seeds were supplied with 1.9 dS/m of nutrient solution every day. The growing tomato plants were ready to be transplanted to the prepared medium after one month. After the transfer to the medium, the tomato plants were then supplied with a 1.9 dS/m nutrient solution for 10 weeks (Rusli et al., 2018), according to the schedule laid out in Table 3. A total of 5,475.75 L of the nutrient solution was supplied to 70 plants, for a total of 10 weeks.

Table 3: Volume of nutrient solution applied per plant by week

Week	volume/plant//d (L)	volume/plant/week (L)
1	0.125	0.875
2	0.250	1.750
3	0.500	3.500
4	0.750	5.250
5	1.000	7.000
6	1.250	8.750
7	1.500	10.500
8	1.800	12.600
9	2.000	14.000
10	2.000	14.000

2.4 Foliar application of chitosan

The chitosan was sprayed onto the leaves of the tomato plants using a hand spray. The chitosan foliar was applied every week after that starting from Week 4, after transplant, up until Week 10. The period of chitosan application was fixed between 6 pm to 7 pm in the evening.

2.5 Observation and data collection

The observation and data collection include plant growth and yield of tomato. Parameters such as pH of the medium (measured using a HI 99121 Direct Soil pH Meter), the height of the plant (cm), and the cumulative weight of fruits (g) were recorded every week after transplanting for 70 d. Other factors such as pest and disease attacks were observed as well by determining the percentage of infected fruits.

3. Results and discussions

3.1 pH medium

Medium pH, one of the essential chemical property measurements, shows the acidity or alkalinity of the media. Figure 2 shows the graph for pH levels in the different zeolite, RHA, and blank media formulations. The results exhibited by most of the media showed that the average media pH value is still at the standard range, which is pH 5.5 to pH 6.8 (Soil Analysis 101, 2014). The acidity of the media is successfully buffered over time because of the presence of zeolite with a high cation exchange and RHA as the soil conditioner (Prasara-A and Gheewala, 2017). The average medium pH value for R30 and R50 was proven to be a good medium for tomato plants as all of them were in the range of pH 5.5 – pH 6.8. For the blank media (C), the pH value over the week shows inconsistency where coco peat does not have the buffering ability like RHA, making it clear

that coco peat alone is not suitable to be used as a media of a plantation in the long run (Barrett et al., 2016). The good pH buffering has added a positive effect to the enhancement of CEC and leading to the uptake of nutrients in the plant.
For R100, the pH is at peak during the beginning of the week. The size of RHA particle is superfine normally ranges 5 to 10 µm (Khan et al., 2015) and when the RHA was used 100% as a medium, it became compact causing the nutrient to accumulate. The accumulation of nutrients in R100 medium affects the inconsistent pH.

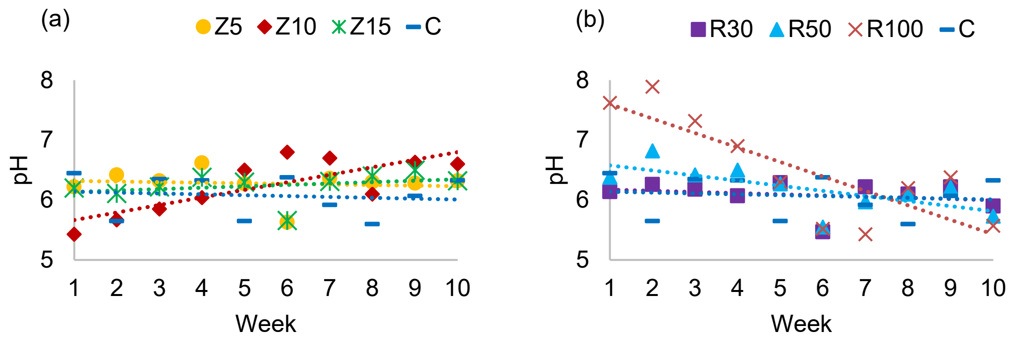

Figure 2: pH measurements for each media formulation for 10 weeks a) Zeolite formulations media b) RHA formulations media

3.2 Height of plants

The evaluation of different formulations of zeolite and RHA on plant height of *Solanum lycopersicum* is shown in Figure 3.

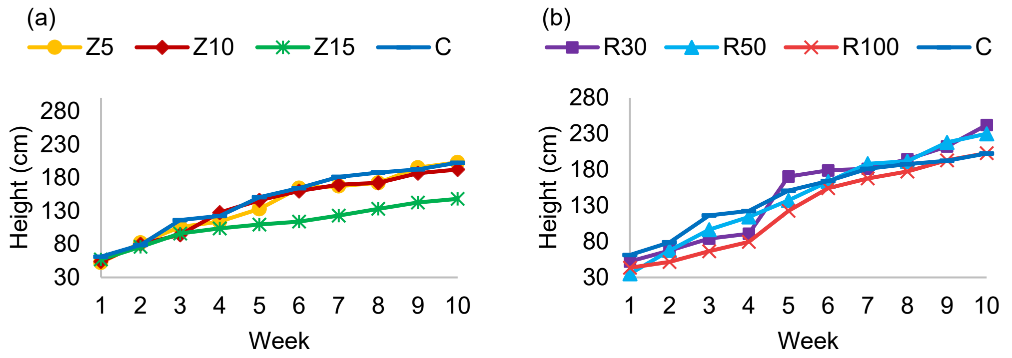

Figure 3: Average height of plants over the weeks for a) zeolite formulations media and b) RHA formulations media

Based on Figure 3, the % growth rate of each plant is calculated using Eq(1).

$$Percent\ growth\ rate\ (\%) = \frac{\left(\frac{S2 - S1}{S1}\right) \times 100}{T} \quad (1)$$

where S1 is the height measurement for Week 1 and S2 is the height measurement for Week 10. T is for the days between each measurement, which in this case is 70 d. The rate of growth (ROG) of Z5, Z10, Z15, R30, R50, R100, and C are 2.56, 3.46, 3.10, 4.55, 3.92, 2.99, and 3.76 % daily. The ROG for R30 is the highest among all and the lowest ROG is Z15. The high silica content (> 90 %) inside the RHA (Fernandes et al., 2017) helps to increase the cation exchange capacity (Greger et al., 2018), where plants are able to take up the positively charged nutrients and avoid leaching. Z15 shows the lowest ROG recorded. Based on the observation, the medium of zeolite mixture became compact after a few weeks due to zeolite granules contain mostly clay. Due to compactness medium, it hindered roots to grow and reduce the plant growth.

3.3 Fruit yield

The ripe tomatoes were harvested in Week 7 (45 d) and graded according to marketability and size. The size of the fruits was benchmarked with the commercial tomato average size of 24 mm. The non-marketable fruits are fruits that are infected, have ripped skins, and are smaller than commercial-sized tomatoes. There is also a small number of oversized tomatoes. Table 4 shows the yield of the non-marketable (%) and marketable fruits for different medium formulations. The R50 produced the most marketable fruits, although the blank media had the highest yield (2,668.0 g).

Table 4: The yield and non-marketable (%) and marketable (g) tomato fruits

Medium Formulation	Yield (g)	Non-Marketable (%)	Marketable (g)
Z5	2,041.0	50	1,020.5
Z10	1,489.0	30	1042.3
Z15	2,548.0	55	1,146.6
R30	1,580.5	1	1,564.7
R50	1,628.5	1	1,612.2
R100	282.0	1	279.1
C	2,668.0	60	1,067.2

A good pH buffer in an RHA formulation can contribute towards positive results for the tomato fruit yield where the RHA can act as a soil conditioner, insecticide, and bio-fertilizer (Prasara-A and Gheewala, 2017). As a result, the growth of plants with the content of RHA is optimum according to the pH conditions, and quicker compared to zeolite during the flowering and fruit-set stages. 1 % of non-marketable fruits (R30 and R50) is caused by the blossom end-rot (BER) disease that was found in the fruit due to the lack of calcium absorbed by the plant to the fruit.

Table 4 shows a high non-marketable yield for tomatoes using media formulations Z5, Z10, and Z15. This is due to the size of the tomatoes that are smaller compared to the size of commercial tomatoes. Figure 4 shows that the size of tomatoes grown using zeolite are smaller than those grown using RHA. This is because, zeolite captures the fertilizer, water, and retains the nutrients such as ammonium for the plant. The availability of nitrogen content in the medium that can be uptake by the plant decreased by 66 % to 78 % (Reyes and Ibarra, 2018). Although coco peat has the highest yield (2,668 g), the amount of non-marketable fruits is also the highest among all, which leads to a total of 1,067.2 g of marketable fruits. The small size of tomatoes is caused by insufficient nutrients that are crucial to help healthier and bigger tomatoes to grow, from being absorbed. CEC allow fertilizers to retain in the soil to ensure the nutrients are taken by the plant and not leached from the media. R100 shows a significant negative result for yields because six out of ten plants died at Week 7, contributing to the fewer amounts of fruit and lower yield. R100 medium structure is compact causes the roots find it harder to grow (Rhoades, 2020). Plants produce fewer roots and take in less nutrients and water resulting poor growth and eventually died.

Figure 4: Comparison of tomato fruits from the different types of media formulations

3.4 Effect of chitosan on blossom-end rot

The chitosan application showed a positive effect in preventing diseases in tomato plants, which are mostly caused by blossom-end rot. The use of chitosan showed a significant increase in marketable fruit yield and low in diseased fruit (El-Tantawy, 2009). The result was obtained by observing the fruits that have black flatten spot at the end of the fruit (Figure 5). The antimicrobial properties of chitosan were also observed. In the experiment, it was estimated that 5 % of the total yield without chitosan were attacked by anthracnose disease compared to only 1 % with chitosan. Based on Ali et al. (2012), the decrease of diseases in papaya plants was due to the induction of antifungal hydrolases such as chitinase, β-1,3-glucanase, and chitosanase that can be found in chitosan. It can also be proven by Malerba and Cerana (2018) during which the seeds soaked once and leaves sprayed every day with chitosan induced the resistance of tomato plants to *Phytophtora infestans* and *Alternaria solani*, microorganisms that caused late and early blight to tomato plants. In this study, chitosan was proven to be able to control blossom-end rot disease in tomato fruits.

(a) (b)

Figure 5: (a) fruit that infected with blossom-end rot; (b) healthy tomato fruit

4. Conclusions

In conclusion, the total marketable fruits acquired were 1,612.2 g for R50, followed by R30 with 1,564.7 g. It is clearly shown that R50 had the best production of *Solanum lycopersicum* compared to other formulations with an average pH 5.5 to pH 6.8 and a minimum percentage of non-marketable fruits. The application of RHA in agriculture as the source of fertilizers and soilless medium can be further explored as it does show the capability to become a safer approach for the environment compared to other chemical-based methods. Chitosan has been proven to offer positive effects in plant immunity against plant pathogens that can cause diseases to tomato plants.

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