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Comparative Evaluation of Media Types in Aquaponic Systems for Tomato Growth and Yield

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate the performance of tomato crops grown in four different media in a bell siphon arranged aquaponics system.
Study Design: completely randomized design.
Place and Duration of Study: Hi-tech Research and Training Unit (HTR&TU), Instructional Farm (IF), Kerala Agricultural University, Vellanikkara from 03-08-2021 to 03-01-2022 and 01-02-2023 to 30-06-2023.
Methodology: An aquaponic system was equipped with twenty-four media beds with bell siphons, three filter tanks (sedimentation tank, mechanical filter, and biofilter), three fish tanks having 1000L

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capacity each, a submersible pump, and two aerators. Two hundred genetically improved farmed tilapia (GIFT) fingerlings were grown in the fish tanks. Four types of media, viz., 20mm gravel (M1), 8-20mm broken tiles (M2), 8-15mm hydroton (M3), and 8-10mm gravel (M4), were filled in the media beds. The two varieties of tomato, Manulakshmi and Yakamoz RZ, were raised. Plant height, plant spread, days to first flowering, days to first harvest, total yield, and average fruit weight were observed to compare the crop performance in each media and identify the best-performing media in an aquaponics system.

Results: During the first and second seasons of Manulakshmi in the aquaponics system, plants grown in 8-10mm gravel exhibited significantly superior results than all other media. The maximum plant spread (66.833cm), plant height (140.556cm), total yield (1.730Kg), and average weight of fruit (38.433g) were observed in 8-10mm gravel during the first season. In the second season of Manulakshmi, the observed plant spread, plant height, total yield, and average weight of fruit were 140.778cm, 66.556cm, 1.729Kg and 38.611g, respectively. In the first season of Yakamoz RZ in the aquaponics system, maximum plant height (145.222cm) and total yield (3.871Kg) were observed in 8-10mm gravel, whereas maximum plant spread (50.500cm) was observed in 20mm gravel. The days to first flowering and days to first harvest were comparatively shorter in 8-10mm gravel in both varieties.

Conclusion: Plants grown in 8-10mm gravel exhibited superior results than all other media. Variations of plant characteristics among different media in the aquaponics system reveal that 8-10mm gravel is more favorable for the growth and yield of tomato plants than other media.

Keywords: Aquaponics; soilless media; tomato; crop growth; yield.

1. INTRODUCTION

India is one of the largest agricultural commodities producing countries on a global basis, utilising more than half of its land area for crop production. There has been a remarkable increase in agricultural productivity over the last decades [1]. On the contrary, Indian agriculture is riddled with the challenge of feeding an escalating human population in the foreseeable future. The intensity of population in Kerala is 35 million (World population review), which is 2.5% of India's population. Kerala's land is three times as densely settled as the rest of India. The unavailability of land, unpredictable climatic conditions, disinterest of youth in agriculture, scarcity of labour, high labour wages, and inadequate market facilities prevent the state from realizing its production potential [2-4]. Improved agricultural production systems can be a sustainable way of addressing this issue. To sustain a balance between food security and crop production, aquaponics within greenhouse technology could be exploited. The use of aquaponics methods holds the potential to significantly contribute to food provision and address global challenges, including water scarcity, food security, water pollution, high energy consumption, and the extensive transportation of food over long distances [5]. The aquaponics system establishes a symbiotic relationship between the fish and plants, where the fish provide nutrients to the plants, and in return, the plants purify the wastewater by utilizing these nutrients within the environment where the fish reside [6,7,8]. Aquaponics has been recognized as a forward-thinking farming approach combining aquaculture system, filtration system, and hydroponics system, which involves crop production in a soilless substrate. In hydroponics systems, plants growing in the soilless medium may comprise of perlite, vermiculite, rock wool, peat moss, coir, composted pine bark, sawdust, sand, or gravel [9,10]. Studies indicate that the choice of soilless media significantly influences nitrifying bacteria counts [11]. Graber and Junge (2009) have revealed that the integration of aquaculture and hydroponics systems can be utilized for producing fish and vegetables like aubergine, tomato, and cucumber suitable for human consumption. Hence, a study was conducted to evaluate the performance of two varieties of tomato in an aquaponic system in two different seasons and find the best media giving better results with each variety.

2. MATERIALS AND METHODS

The study was carried out at Hi-tech Research and Training Unit (HTR&TU), Instructional Farm (IF), Kerala Agricultural University, Vellanikkara. The experiment was conducted in a polyhouse located at 10°32'50" North latitude and 76°16'18" East longitude.

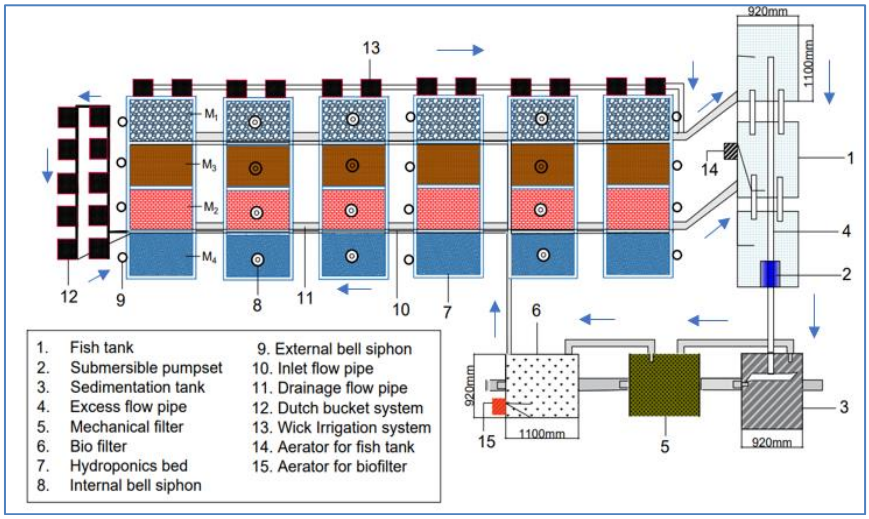

Fig. 1. The schematic representation of system

The applied method encompassed an aquaponic system consisting of twenty-four media beds with bell siphons, three filter tanks (sedimentation tank, mechanical filter, and biofilter), three fish tanks having 1000 l capacity each, a submersible pump, and two aerators. The system was designed in such a way that nutrient-rich water circulates throughout day and night.

A field experiment was laid out in a completely randomized design. A naturally ventilated polyhouse with a floor area of 150 m² was selected for the study [12]. Three intermediate bulk container (IBC) tanks (1.1m x 0.92m x 1m) served as nutrient water reservoirs as well as fish culture tanks. An aerator with six knobs, an air output of 10 l/min was used to provide oxygenation in both systems. The water was channelled from the fish tank to the sedimentation tank, the mechanical filter, the biofilter, and finally to the hydroponic beds where plants were cultivated. A bypass arrangement was provided so that the excess flow from the pump was redirected back to the fish tank. The filtered water from the sedimentation tank was transferred through an inlet connection to the bottom of the mechanical filter and then to the biofilter. After completing the filtration process in the sedimentation tank, mechanical filter, and biofilter (removing soluble and insoluble unwanted impurities), water was allowed to flow into the hydroponics system through the main pipe and laterals. Two inlets were provided in each bed. The outflow from each bed was allowed to flow into the drainage pipe. Two hundred genetically improved farmed tilapia (GIFT) fingerlings were introduced into the fish tanks in proportions of 70, 70, and 60 in the first, second, and third tanks, respectively. Used barrels were cut horizontally into two equal halves and were used for making two media beds. Four types of media, *viz*., 20mm gravel (M_1), 8-20mm broken tiles (M_2), 8-15mm hydroton (M_3), and 8-10mm gravel (M_4), were filled in the beds. The comparative evaluation of the media was conducted by raising two varieties of tomato, Manulakshmi and Yakamoz RZ, from 03-08-2021 to 03-01-2022 and 01-02-2023 to 30-06-2023. Two tomato varieties were transplanted in groups of three in each bed with 50x50cm spacing. Plant height and plant spread were observed at 14 days after planting (DAP), 28 DAP, 42 DAP, 56 DAP, 70 DAP, and 84 DAP. Days to first flowering and first harvest were also observed. The weight of a single fruit harvested at different stages and the total yield of the tagged plant were noted. The comparison of media within the system was statistically analysed using Analysis of Variance (ANOVA).

3. RESULTS AND DISCUSSION

The analysis of growth parameters of Manulakshmi in aquaponics system during the first and second seasons (Tables 1 and 2, respectively) showed that the plants grown in M_4 media were significantly higher than those of all other medias during the first season, followed by M_1 media (20mm gravel). Among all the treatments, plants grown in 8-10mm gravel exhibited the highest plant height (140.556 cm, 140.778 cm) as well as plant spread (66.833cm, 66.556 cm) and shortest days to flowering

(53.889 days, 53.889 days) during the first and second seasons. The plant parameters in M_2 and M_3 were on par with each other. The variations of plant characteristics among different media in the aquaponics system reveal that 8-10mm gravel is more favorable for the growth and yield of tomato plants than other media. This is due to the size and shape of the particles in the 8-10mm gravel. Moreover, this media does not clog frequently, and algae formation was negligible compared to all other media. The aeration and root-holding strength are also higher in the case of 8-10mm gravel. The results are in line with the findings of Suseela [13].

The analysis of growth parameters of Yakamoz RZ in aquaponics system during the first and second seasons is summarized in Tables 3 and 4, respectively. It reveals that plants grown in M_4 media were significantly superior to all other medias during both seasons. The plant spread of Yakamoz RZ in M_1 media was significantly higher than that of all other medias.

Table 1. Growth parameters of Manulakshmi in aquaponics system during first season

Media	Plant height	Plant spread	Days to first flowering
M_1	135.111± 3.756 [b]	63.167 ± 1.732 [b]	57.667± 2.179 [b]
M_2	129.333± 3.606 [c]	60.333± 2.062 [c]	61.778± 1.093 [c]
M_3	125.889± 3.333 [c]	58.500± 2.092 [c]	60.000± 2.000 [c]
M_4	140.556± 3.575 [a]	66.833± 2.739 [a]	53.889± 1.167 [a]
F- Value	29.470	24.832	36.980
P- Value	< .001	< .001	< .001
CD (0.05)	3.434	2.103	1.617

Table 2. Growth parameters of Manulakshmi in aquaponics system during second season

Media	Plant height	Plant spread	Days to first flowering
M_1	135.333± 1.871[b]	62.778± 1.856 [b]	56.444± 1.236 [b]
M_2	129.889± 1.833[c]	59.667± 2.000 [c]	62.222± 0.667 [c]
M_3	126.111± 1.900 [c]	58.111± 1.900 [c]	59.889± 1.167 [d]
M_4	140.778± 2.438 [a]	66.556± 1.590 [a]	53.889± 0.782 [a]
F- Value	89.961	36.864	123.718
P- Value	< .001	< .001	< .001
CD (0.05)	1.948	1.772	0.955

Table 3. Growth parameters of Yakamoz RZ in aquaponics system during first season

Media	Plant height	Plant spread	Days to first flowering
M_1	139.222± 3.528[b]	50.500± 1.436[a]	51.444± 3.087[a]
M_2	133.667± 2.646[c]	48.111± 1.965[b]	57.778± 1.787[b]
M_3	130.889± 2.261[c]	46.222± 1.481[b]	55.000± 3.000[b]
M_4	145.222± 4.410[a]	46.111± 2.421 [b]	50.556± 2.603[a]
F- Value	32.932	10.912	14.018
P- Value	< .001	< .001	< .001
CD (0.05)	3.189	1.798	2.567

Table 4. Growth parameters of Yakamoz RZ in aquaponics system during second season

Media	Plant height	Plant spread	Days to first flowering
M_1	139.778± 3.114[b]	54.667± 2.500[a]	53.778± 2.048[ab]
M_2	132.222± 1.856[c]	49.111± 0.928[b]	57.556± 1.509[c]
M_3	131.556± 2.963[c]	48.778± 1.481[b]	56.111± 1.900[bc]
M_4	147.556± 2.506[a]	47.556± 2.506[b]	51.222± 3.232[a]
F- Value	72.008	23.128	13.496
P- Value	< .001	< .001	< .001
CD (0.05)	2.553	1.898	2.179

Table 5. Yield parameters of Manulakshmi in aquaponics system during first season

Media	Days to first harvest	Total yield	Average weight of fruit
M_1	86.444± 1.333 [b]	1.531± 0.061[b]	38.067± 0.472 [a]
M_2	88.889± 1.054 [c]	1.297± 0.087 [c]	38.022± 0.412 [a]
M_3	87.778± 1.563 [bc]	1.330± 0.067 [c]	38.122± 0.393 [a]
M_4	81.778± 1.563 [a]	1.730± 0.064 [a]	38.433± 0.346 [a]
F- Value	45.257	72.902	1.870
P- Value	< .001	< .001	0.155
CD (0.05)	1.341	0.068	0.393

Table 6. Yield parameters of Manulakshmi in aquaponics system during second season

Media	Days to first harvest	Total yield	Average weight of fruit
M_1	86.111± 1.167 [b]	1.541± 0.063 [b]	38.322± 0.427 [a]
M_2	89.444± 1.236 [c]	1.302± 0.078 [c]	38.200± 0.614 [a]
M_3	88.000± 1.225 [c]	1.332± 0.059 [c]	38.200± 0.324 [a]
M_4	81.667± 1.323 [a]	1.729± 0.050 [a]	38.611± 0.451 [a]
F- Value	67.011	89.515	1.560
P- Value	< .001	< .001	0.218
CD (0.05)	1.191	0.061	0.448

Table 7. Yield parameters of Yakamoz RZ during first season

Media	Days to first harvest	Total yield	Average weight of fruit
M_1	78.889± 2.667[a]	3.577± 0.062[b]	88.689± 0.909[a]
M_2	85.778± 2.333[b]	3.203± 0.162[d]	87.911± 1.104[a]
M_3	83.778± 2.108[b]	3.357± 0.092[c]	87.833± 0.971[a]
M_4	78.000± 1.732[a]	3.871± 0.136[a]	88.211± 0.448[a]
F- Value	25.504	52.887	1.697
P- Value	< .001	< .001	0.187
CD (0.05)	2.150	0.114	0.859

Table 8. Yield parameters of Yakamoz RZ during second season

Media	Days to first harvest	Total yield	Average weight of fruit
M_1	77.778± 1.563[a]	3.580± 0.063[b]	88.278± 0.689[a]
M_2	84.000± 2.449[b]	3.246± 0.125[d]	87.978± 0.418[a]
M_3	83.778± 2.539[b]	3.404± 0.061[c]	87.533± 0.758[a]
M_4	76.667± 1.323[a]	3.898± 0.125[a]	88.133± 0.604[a]
F- Value	32.516	72.175	2.354
P- Value	< .001	< .001	0.091
CD (0.05)	1.961	0.096	0.606

The statistical analysis of yield parameters of Manulakshmi in aquaponics system during the first and second seasons is shown in Tables 5 to 6, respectively. The analysis of yield in the aquaponics system showed that the plants grown in M_4 media (1.730Kg and 1.729 Kg) were significantly higher than that of all other medias during the first and second seasons, respectively. The results were in close agreement with the findings of Salam et al. [14] and Gaviria et al. [15]. There was no significant difference between the medias in terms of average weight of fruit. The days to first harvest of Manulakshmi in M_4 were significantly lower than all other medias in both seasons.

The statistical analysis of yield parameters of Yakamoz RZ in aquaponics system during first and second seasons is shown in Tables 7 to 8, respectively. Plants grown in M_4 media had the highest yield than that of all other medias in both seasons. There was no significant difference between the average fruit weight in four media in

both seasons. Yakamoz RZ grown in 20mm gravel and 8-10 mm gravel flowered earlier than that in 8-20mm broken tiles and 8-15mm hydroton.

4. CONCLUSION

The variations of plant characteristics among different media in the aquaponics system reveal that 8-10mm gravel is more favorable for the growth and yield of tomato plants than other media. This is due to the size and shape of the particles in the 8-10mm gravel. Moreover, this media does not clog frequently, and algae formation was negligible compared to all other media. The aeration and root-holding strength are also higher in the case of 8-10mm gravel.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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