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Media Impact on Aquaponics System Performance: A Comparitive Study on Lettuce Crop Parameters

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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 lettuce grown in four different media in a feeder cum operation regulation and ebb and flow siphon arranged aquaponics system and study the effect of media on crop performance.
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 between 16-06-2021 to 26-01-2023 in two seasons
Methodology: The system was set up with 24 media beds with ebb and flow arrangements, a feeder cum operational regulation system, three filter tanks (sedimentation tank, mechanical filter &

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bio-filter), three fish tanks having 1000L capacity each, a submersible pump, and two aerators. Two hundred genetically improved farmed tilapia (GIFT) fingerlings were grown in the fish tanks. Nutrient-rich water was circulated only from 7 am to 7 pm for 15min at every 1h intervals. The water was allowed to flow into sedimentation tank followed by mechanical filter. The sedimentation tank was designed based on the principle of formation of aggregates at the bottom of the system due to the decrease in the velocity of moving particles. The mechanical filter facilitated a two- step filtering and allowed water into biofilter. The filtered water from biofilter enter the media beds. The automatic feeder cum operational regulation system was developed in order to reduce the energy consumption and to ensure trouble-free operation of the system. The experiment was carried out with four treatments and six replications. The 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 media beds. Two varieties of lettuce, Cherokee RZ and Starfighter RZ were raised in the media beds. Plant height, plant spread and average weight of foliage were observed to compare the crop performance in each media and identify the best-performing media in the aquaponics system.

Results: During the first season of Cherokee RZ in aquaponics system the plants grown in 8-20 mm broken tiles (M_2) and 8-10mm gravel (M_4) media aided better growth and development than all other medias. The plant height, plant spread and average weight of foliage were recorded to be 28.573cm, 29.173 cm and 264.193g respectively in M_2 medium and 28.373cm, 28.973 cm and 254.620g respectively in M_4 medium. In the second season of Cherokee RZ also, the observed plant height, plant spread and average weight of foliage in M_2 medium were 28.687cm, 29.313 cm and 265.887g respectively which were comparable to that of plants grown in M_4 medium. In the trial with Starfighter RZ, M_2 media supported highest plant height, plant spread and yield (27.967 cm, 28.553cm and 240.020g respectively) in the first and second seasons (28.073 cm, 28.073 cm and 234.40g respectively).

Conclusion: The 8-15 mm broken tile media was found to be the ideal one supporting better crop performance.

Keywords: Aquaponics; soilless media; lettuce; crop growth; weight of foliage.

1. INTRODUCTION

Aquaponics stands as an exceptionally productive and environmentally sustainable food production system in the realm of self- sufficiency and food security under Kerala conditions. Aquaponics methods confront issues like water scarcity, food security, water pollution, high energy consumption, and the extensive transportation of food over long distances while providing a means for food [1]. It holds the potential to contribute significantly to addressing both planetary boundaries and sustainable development goals, especially in arid regions or areas with nonarable soils [2]. This approach utilizes the nutrient-rich water from fish tanks to irrigate plants in the hydroponic system [3,4]. Nitrifying bacteria play a pivotal role in aquaponic systems. The fish waste transforms into a nutrient source for the nitrifying bacteria. These bacteria convert the potentially harmful byproducts of fish waste into valuable nutrients for plants. Plants extract this nutrient like nitrate and maintain it to the safest level (150-200ppm) for fish. These sophisticated systems incorporate cutting-edge technology, featuring automated monitoring and control systems, advanced pumps and filters, environmental sensors, and data loggers. Generally, three types of aquaponic systems are employed for commercial production, classified based on the types of grow beds, namely Nutrient Film Technique (NFT), Deep Water Culture (DWC), and media-filled or flood and drain systems [5]. Among these approaches, media-based aquaponics is esteemed for its superior efficiency in nitrogen utilization, offering a larger surface area for microbes compared to the other two methods. A media bed is an important component of an aquaponics system that provides oxygen and nutrients to the crop, supports to the root system, and provides a facility for microbial colonisation. This in turn provides better growth and yield of plants. In an aquaponics system, selection of media has greater importance, as the material and size of media depend on the availability of air and nutrients to the plants, and the surface area of the media depends on the density of the population of beneficial bacteria [6,7]. Consequently, it has emerged as the most prevalent and favoured technique for cultivating vegetable crops [8]. Those crops possessing low to medium nutritional requirement such as lettuce, microgreens, and herbs like chives, basil, spinach, and watercress are exceptionally well-adapted to aquaponics [9]. Hence a study was conducted to evaluate the effect of different media on performance of two varieties of lettuce in an automatic aquaponic system in two different seasons and to identify the best media giving better result with each variety.

2. MATERIALS AND METHODS

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. The system was set up with 24 media beds with ebb and flow arrangements, a feeder cum operational regulation system, three filter tanks (sedimentation tank, mechanical filter & bio-filter), three fish tanks having 1000L capacity each, a submersible pump, and two aerators. With the help of this system nutrient-rich water was circulated only from 7 am to 7 pm for 15min at every 1h intervals.

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 [10]. Three intermediate bulk container (IBC) tanks (1.1m x 0.92m x 1m) served as nutrient water reservoir as well as fish culture tank. 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. In each and every bed of the system ebb and flow-type siphons operating with a feeder cum operational regulation system were installed. The nutrient rich water from the fish tank was allowed to flow into the sedimentation tank which was designed based on the principle of formation of aggregates at the bottom of the system due to the decrease in the velocity of moving particles. In this system, the inflow from the fish tank was not allowed to move directly into the sedimentation tank, but it was allowed to flow into a pipe having a larger diameter [11]. Afterwards, the nutrient water was allowed to move downward through the space between the inlet pipe and larger pipe which increased the rate of sedimentation of the solid particles. The sludge was allowed to settle at the bottom of the tank and was periodically removed using an outlet setup. The filtered water from sedimentation tank was allowed to flow through mechanical filter which facilitated two step filtering. Even though the sedimentation tank and mechanical filter helped remove the suspended solids from the nutrient water, it contained tiny particles and soluble matter, which were harmful to the fish. Hence a biofilter equipped with microorganisms was installed for converting these harmful materials to plant nutrients [10,11].

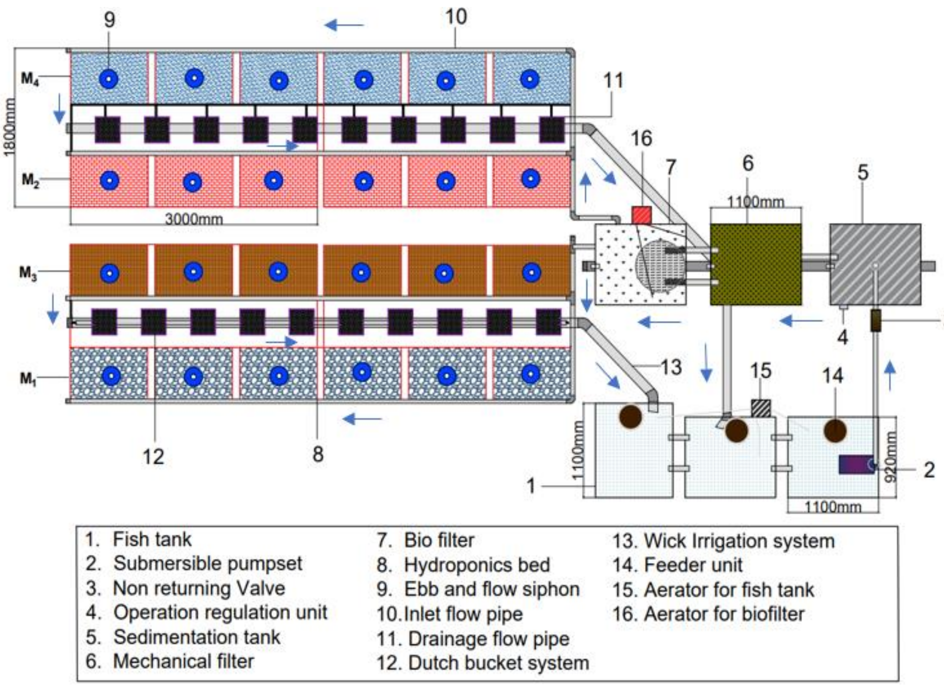

Fig. 1. The schematic representation of system

After completing the filtration process through three filter tanks (sedimentation tank, mechanical filter and biofilter), water was allowed to flow into media beds. Used barrels were cut horizontally into two equal halves and were used for making two media beds. Four types of media *viz*. 20mm gravel, 8-20mm broken tiles, 8-15mm hydroton, and 8-10mm gravel were filled in the beds. The comparative evaluation of the media was conducted by raising two varieties of lettuce, Cherokee RZ and Starfighter RZ during the periods from 16-06-2021 to 29-07-2021and from 14-12-2022 to 26-01-2023. Both lettuce varieties were transplanted into three beds of each media. Five plants were selected per replication for this study. The growth parameters like plant height, plant spread and total weight of foliage of both varieties, in accordance with fish growth, were monitored. The comparison of media within the system was statistically analysed using Analysis of Variance (ANOVA).

3. RESULTS AND DISCUSSION

The Statistical analysis of crop parameters of Cherokee RZ in aquaponics system in the first revealed that (Table 1) the plants grown in 8-20mm broken tiles (M_2) and 8-10mm gravel (M_4) media aided better growth and development than all other medias during the first season. There was no significant difference between M_2 and M_4. The plant height and plant spread of plants grown in M_2 were recorded to be 28.573cm and 29.173cm respectively whereas 28.373cm and 28.973cm respectively in the case of plants grown in M_4 media during the first season. The highest yield in terms of total weight of foliage was achieved in M_2 (264.193g) followed by M_4 (254.620g).

During the second season also, the treatments M_2 and M_4 were superior ones and had no significant difference between them (Table 2). The plant height recorded in M_2 and M_4 media were 28.687cm and 28.520cm respectively. The highest plant spread was observed in plants grown in M_2 (29.313cm) and M_4 (29.147cm) media. The foliage obtained per plant was higher in plants grown in M_2 media (265.887g) followed by M_4 media (253.533g).

The statistical analysis of crop parameters of variety Starfighter RZ cultivated in each media during first and second season are detailed in Tables 3 and 4 respectively. When Starfighter RZ crop was raised, the superiority of M_2 medium was evident over all other media. The results obtained during first season is presented in Table 3. The broken tile media supported highest plant height (27.967cm), plant spread (28.553) and yield (240.020g) in the first season of trial. All crop parameters were recorded to be lower in 8-15mm hydroton medium compared to other media. During the second season also, the results obtained with M_2 medium were statistically superior and most promising. 8-20mm broken tiles was regarded as the best media in supporting highest vegetative growth. The highest plant height was observed in M_2 media (28.073cm) followed by M_4 media (27.660cm) in the feeder cum operational regulation system arranged aquaponics system. The variation in growth characteristics reveal that crops grown in broken tiles yielded the highest, whereas those in hydroton showed the lowest yield. This variation is attributed to differences in the physical and biological properties of the media used for cultivation. In aquaponics systems, the size and shape of the media are critical factors influencing plant growth. Smaller, flatter media particles offer increased surface area for root contact with nutrient-rich water compared to round particles. Therefore, broken tiles, which are flatter in shape compared to gravel, promoted greater plant spread, whereas hydroton, nearly round in shape, exhibited minimal plant spread. The result is in close agreement with Suseela [12]. The findings of Blidariu et al. [13] was not in confirmation with the results of the study who reported the superiority of hydroton media in giving higher biomass and yield compared to plants grown in gravel media [14,15].

Table 1. Crop parameters of Cherokee RZ in aquaponics system during first season

Media	Plant height	Plant spread	Total weight of foliage
M_1	27.620 ± 0.283 b	28.207 ± 0.291 b	244.240 ± 4.447 c
M_2	28.573 ± 0.183 a	29.173 ± 0.183 a	264.193 ± 6.006 a
M_3	27.200 ± 0.391 c	27.987 ± 0.177 b	230.087 ± 5.106 d
M_4	28.373 ± 0.320 a	28.973 ± 0.320 a	254.620 ± 4.037 b
F- Value	67.191	79.272	130.485
P- Value	< .001	< .001	< .001
CD (0.05)	0.222	0.183	3.619

Table 2. Crop parameters of Cherokee RZ in aquaponics system during second season

Media	Plant height	Plant spread	Total weight of foliage
M_1	27.967 ± 0.344 b	28.513 ± 0.331 b	231.667 ± 5.164 c
M_2	28.687± 0.245 a	29.313 ± 0.272 a	265.887 ± 4.941 a
M_3	27.333 ± 0.274 c	27.913 ± 0.223 c	219.533 ± 5.668 d
M_4	28.520 ± 0.305 a	29.147 ± 0.334 a	253.533 ± 5.975 b
F- Value	64.876	71.169	220.929
P- Value	< .001	< .001	< .001
CD (0.05)	0.215	0.214	3.982

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

Media	Plant height	Plant spread	Total weight of foliage
M_1	26.993± 0.212 ^{c}	27.573 ± 0.212 ^{c}	210.973 ± 5.101 ^{c}
M_2	27.967 ± 0.180 ^{a}	28.553 ± 0.185 ^{a}	240.020 ± 6.587 ^{a}
M_3	26.720 ± 0.221 ^{d}	27.333 ± 0.244 ^{d}	193.767 ± 4.664^d
M_4	27.667 ± 0.172 ^{b}	28.307 ± 0.175 ^{b}	230.007 ± 5.880^b
F- Value	128.948	119.725	201.016
P- Value	< .001	< .001	< .001
CD (0.05)	0.144	0.150	4.094

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

Media	Plant height	Plant spread	Total weight of foliage
M_1	26.980 ± 0.246 ^{c}	26.980 ± 0.246 ^{c}	209.067 ± 4.758 ^{c}
M_2	28.073 ± 0.167 ^{a}	28.073 ± 0.167 ^{a}	234.400 ± 6.759 ^{a}
M_3	26.560 ± 0.168 ^{d}	26.560 ± 0.168 ^{d}	193.800± 5.144 ^{d}
M_4	27.660 ± 0.180 ^{b}	27.660 ± 0.180 ^{b}	226.600 ± 4.748 ^{b}
F- Value	184.797	184.797	169.075
P- Value	< .001	< .001	< .001
CD (0.05)	0.140	0.140	3.955

4. CONCLUSION

The 8-15 mm broken tile media was found to be the most congenial substrate for the better growth and yield of lettuce. The highest plant height, plant spread and average weight of foliage was obtained from plants grown in broken tile medium followed by 8-10mm gravel medium.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare 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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