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Production of Butterhead Lettuce and Cherry Tomato by Hydroponic System

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Hydroponic commonly incorporates crops farming with less usage of chemical fertilisers and soil utilisation. The existing hydroponic systems can only show essential parameters such as humidity, water level, nutrients and light intensity. Nutrient Film Technique (NFT) system with portable monitoring device, S shaped UPVC pipe, wood, net protection, pH meter, electrical conductivity (EC) meter, growing media for growing cherry tomato and butterhead lettuce in a netting system environment was developed which includes determination of pipe size, flowrate, angle of pipe degree and pump size. The experiment was laid out in a randomised complete block design (RCBD) with three treatments of growing media (perlite, clay pebbles and coco fibre) and ten replications for each treatment. Plant lengths, total count of harvested cherry tomato, yield (g), pH and EC values were recorded during the study. The results showed that flowrate (Q) was 117.9 (L/h) through a 7.62 cm UPVC pipe diameter and a 90-degree elbow joint with pump power of 0.193 watts. Mean comparison of plant lengths between treatments for butterhead lettuce planting shows coco fibre produces highest leaf lengths while cherry tomato planting shows clay pebbles produces highest stem lengths. In terms of plant yield (g) and total count of harvested cherry tomato and butterhead lettuce, clay pebbles media recorded the highest values for both crops and showed significant differences to other growing media.

Keywords: *Nutrient film technique, pH meter, EC meter, yield, planting media, stem height and leaf lengths.*

Food security is becoming an alarming issue as the human population dramatically increases and sufficient food supply is required for the people. Estimated world population will reach 9.7 billion in 2050 from the current population of 7.7 billion (UN DESA, 2019). In fact, 80 per cent of the world's settlements would be concentrated in and around the urban areas (Ajay & Sheeja, 2016). Urban farming could be one of the solutions that can help to tackle the food security issues by utilising hydroponic planting system (FAO, 2013). Hydroponic by definition is a method of planting crop in a water-based rich solution with less usage of fertilisers and soil (Keith, 2003). Instead of using soil, growing media such as perlite, rock wool, clay pellets, peat moss and vermiculite can be used. The hydroponic structure is constructed in a secure surrounding. The crops that mature in the structure, possess the

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possibility to improve when deprived of sunlight (Crisnapati *et al.*, 2017). As a result of reduced sunlight, the growth of algae in crops nutrient solution which are wide-open is inhibited (Umamaheswari *et al.,* 2017). In a nutshell, hydroponic is to remove as many barriers as possible to allow crop to thrive in a controlled environment.

Hydroponics is utilised for crop production in environmentally-controlled farming structure, for instance, plant factories growing leafy vegetables such as lettuce, basil and spinach. In fact, tomato has also been planted widely in the plant factory-controlled environment due to many benefits. Growing media is one of the noteworthy features in nurturing activities for the motive that it will standardise the attainment rate of the developing plant. Hydroponics structures contain all benefits of the more efficient land use such as, higher quantity, abundant harvests and production of cleaner products. Progressively it is feasible to reduce use of water and fertilisers and is less complex in pest and disease control (Andaluz *et al.*, 2016). Better understanding of the electrical conductivity (EC) in nutrients, changes in pH, air temperature, water temperature and light force variation in the hydroponic system can promote improvement of the hydroponics plants especially for most vegetable crops. In order to achieve good vegetable harvests, agriculturists should consistently pay attention to factors such as fertiliser content, water temperature, pH adjustment, EC sustenance, light intensity and air temperature variation inside the hydroponic planting medium (Siregar *et al.,* 2018).

The cultivator within the existing hydroponic system can only show essential parameters such as humidity, water level, nutrients and light intensity using smart monitoring devices (Eridani *et al.*, 2018). There is no further study made on the design of the Nutrient Film Technique (NFT) system for growing cherry tomato (*Solanum lycopersicum*) and butterhead lettuce (*Lactuca sativa* var. *capitate*) incorporating pipe size, flowrate, angle of pipe degree and pump size to know the interaction of the nutrient mixing rate and the growing media. Hence, the best planting media for hydroponic system for optimum holding of the mixture of fertiliser content for butterhead lettuce and cherry tomato planting had high variations of suggestions. Therefore, this study was to develop a NFT hydroponic system design for growing cherry tomato and butterhead lettuce; which includes design of pipe size, angle of pipe degree, flowrate and pump size. The study of the interaction of the nutrient mixing rate and the growing media which can make it easier to determine the most suitable fertiliser mixture rate for butterhead lettuce and cherry tomato growth were also incorporated. Moreover, the need for suitable planting media for hydroponic system for holding the mixture of fertiliser content in the different media was determined throughout this study.

MATERIALS AND METHODS

Experiment location

The experiment was conducted at the Faculty of Engineering, Universiti Putra Malaysia (2.9993° N, 101.7079° E), from 1 January until 30 March, 2019.

Hydroponic fabrication

This methodology applied to the fabrication and performance evaluation of S shaped hydroponic system under protected structures. The NFT design process was performed by using Autodesk AutoCAD 2017 (Lenord *et al.,* 2014). The NFT design for both crops,

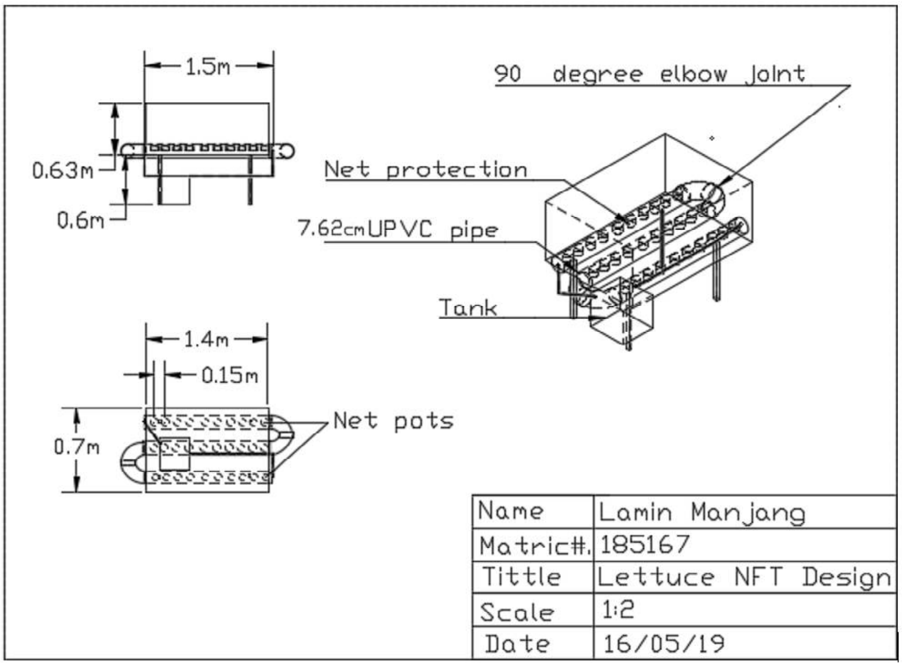


Figure 1 NFT system design for butterhead lettuce

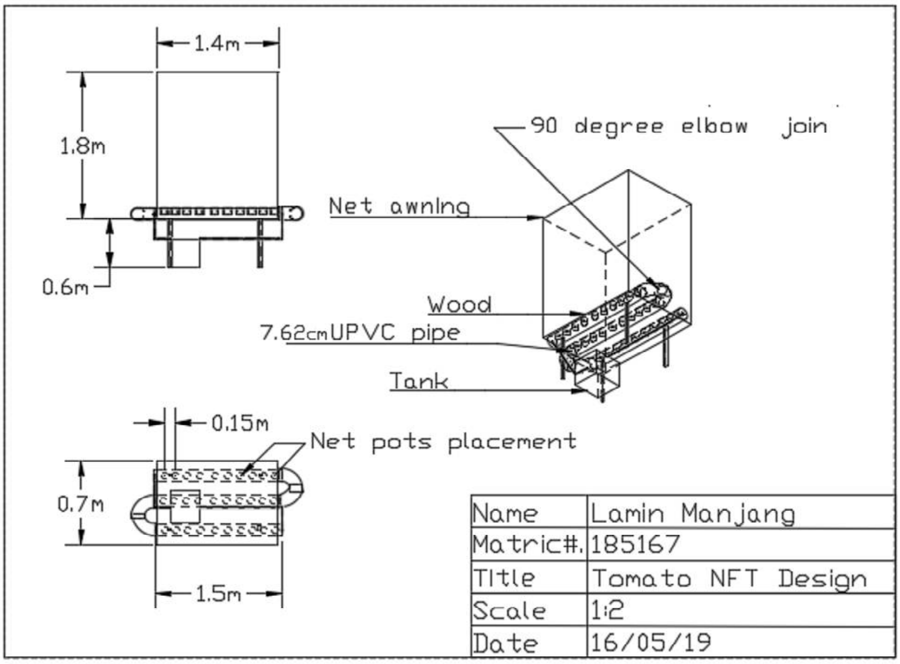


Figure 2 NFT system design for cherry tomato

butterhead lettuce and cherry tomato can be viewed in *Figures 1* and *2*. Similar design and structure pattern for the hydroponic system structure was used for both the plants. Unplasticised polyvinyl chloride (UPVC) pipes of 7.62 cm in diameter and 1.5 m in length were constructed. These pipes were connected using a 90° elbow joint with a net pot spacing of 0.15 m through the manifolds, and 80-litre guppy tank for the storage of the nutrients and water that needs to be supplied through the pipes simultaneously to the crop by a submersible pump. A wooden structure was fabricated to serve as base support for this NFT system with head height of 0.6 m from the ground and distance of 1.4 m supporting the pipes weight with liquid nutrients. However, in terms of the net protection, as the heights of the crops varied, the net protection setting for butterhead lettuce planting was constructed at a height of 0.63 m while that for the cherry tomato was constructed at 1.8 m. The construction of the net protection through wooden support for the system was mainly to prevent direct sunlight penetration and pest attacks to the crops (Sihombing *et al.*, 2018).

Flowrate (Q) and pump size determination

The planning for fabrication and performance evaluation of S shaped UPVC pipe hydroponic system were determined. The components that were included in this study were the angle of UPVC pipe, wood, net protection, pH meter, EC meter, and three types of growing media. The determination of pipe size, flowrate, degree angle of pipe and pump size were performed to study the interaction of the nutrient mixing rate and the growing media and the need of suitable planting media for hydroponic system for holding the mixture of fertiliser content in those different media. The Manning's equation for determining the flowrate (Q) through the NFT hydroponic system were carried out using the equations (1), (2), (3), (4) and (5).

$$A = \pi r^2 \tag{1}$$

Where, A is the area (m^2), π is dimensionless with value 3.142, r is the radius (m).

$$P = \frac{1}{2}\pi r^2 + d \tag{2}$$

Where, P is the perimeter (m), d is the diameter (m).

$$R = A/P \tag{3}$$

Where, R is the hydraulic radius (m).

$$V = \frac{k}{n} R_3^2 S_2^1 \tag{4}$$

Where, V is the velocity (m/s), K is a constant with value 1, n is the manning roughness with value 0.011 (Engineering Tool Box, 2004). S is the channel slope (m/m) with value 0.001. Therefore,

$$Q = AV \tag{5}$$

While for determination of suitable pump size for the system or power t needed to transmit the fluid by the pump in watt (P), with determined flowrate (Q) equation (6) was used.

$$P = QpH9.81 \tag{6}$$

Where, P is the pump power (watt), Q is the flowrate (m^3/s), p is the density of the liquid (kg/m^3), H is the piezometric height of water (m), and 9.81 is the average intensity of gravity.

Maintenance of this NFT system was performed on weekly or daily basis including upscaling or downscaling water and nutrients, pH and EC monitoring and controlling, flushing out accumulated nutrients, etc.

Experimental design

The treatments for each crop comprised of three different types of soilless media mixture of perlite, clay pebbles and coco fibre as shown in *Table 1*. The treatments with ten replications were arranged in the randomised complete block design (RCBD). Each unit/system has three manifolds and each manifold had ten holes; with a plant in each hole.

The seedlings of butterhead lettuce and cherry tomato were transplanted into the hydroponic system after 14 days of germination in the gardening tray. The hydroponic system was designed and developed with the help of locally available materials and resources as can be seen in *Figure 1*. The S shaped UPVC pipe used in the hydroponic system has to be rigid and strong as all parts are mounted on it. The S shaped structure fabrication can be seen in *Figure 3*.

Concentration of nutrients solution

Nutrients solution is the most important chemical of the hydroponic system. In the present study the nutrient solution was prepared by mixing together the solutions A and B. The solutions A and B were made from the mineral salts where solution A mostly contained calcium nitrate and chelated iron, while solution B mainly contained epsom salt, monopotassium phosphate and trace elements. The concentration rates for both the solutions are shown in *Table 2*. The pH (5.5 - 6.0) and EC (2.0 - 5.0) of the solution were retained for cherry tomato planting while for butterhead lettuce planting pH of 6.0 - 6.5 and EC of around 0.8 - 2.0 were maintained (Saaid *et al.*, 2013).

Plant measurement and statistical analysis

Measurement such as plant lengths, total count of cherry tomato, yield (g), pH and EC values for both crops (butterhead lettuce and cherry tomato) were measured every 7 days until the harvesting process. The butterhead lettuce was harvested on the fifty-seventh day of planting while for the cherry tomato, harvesting process was started from the sixty-seventh day of planting onwards. Data were subjected to analysis of variances by using Statistical Analysis System Software (SAS 9.1) and differences between treatments means were compared by using Tukey's honest significant difference (HSD) test at 0.05 probability level.

RESULTS AND DISCUSSION

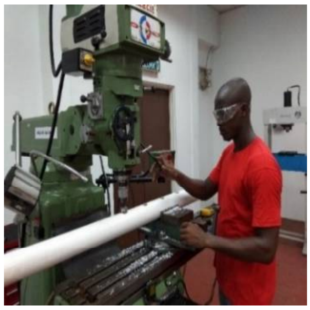
Pipe flowrate and pump power

The Manning's equation was considered and used in determining the flowrate through the 7.62 cm UPVC pipe for the NFT hydroponic system. The flowrate through the UPVC pipe required for the NFT system for the butterhead lettuce and cherry tomato, the parameters such as: area, $A = 4.560e\text{-}3m^2$, the perimeter, $P = 0.0785$ m, hydraulic radius, $R = 0.0581$ m, velocity, $V = 0.431$ m per minute, was used and it was determined that flowrate (Q) was 117.9 L per hour for the hydroponic system. The recommended flowrate was usually in a range of 1 - 2 litre every minute for each

TABLE 1
TREATMENTS WITH DIFFERENT TYPES OF GROWING MEDIA

Treatments	*Number of plants*	*Implements*
T1	10	UPVC pipe + hydroponic solution + perlite
T2	10	UPVC pipe + hydroponic solution + clay pebbles
T3	10	UPVC pipe + hydroponic solution + coco fibre

a) PVCs and woods needed in workshop technology lab - cut according to size and gathered..



b) Drilling 45 mm diameter holes for placement of net pots, using the milling machine.

c) The PVCs and the base wood stand support cut using the vertical saw machine and assembled together using nails and hammer.

d) Finished and assembled PVCs and base wood stand support.

e) Assembling ceiling wood for net protection/awning.

f) The completed ceiling wood assembly with net protection/ awning.

Figure 3 S shaped UPVC pipe hydroponic system fabrication and its structure

developed pipe canal or extending from 60 to 120 litres for each hour.

In order to determine suitable pump size for the system, pump size, P need to be calculated first. This NFT system used flowrate of (Q) = 3.275e-5 m^3 per second, density of the liquid (p) = 1000 kg per cubic metre, piezometric height of water (H) = 0.6 m, with consideration of the average intensity of gravity = 9.81, so pump size calculated for the system,

TABLE 2
CONCENTRATION RATE OF DIFFERENT NUTRIENTS SOLUTION USED IN THE STUDY

Solution A	*Solution B*
N - 15.5%	N - 7%
CaO - 26%	P_2O_5 - 9%
Fe-EDTA - 1.32%	K_2O - 37%
	MgO - 3 %
	SO_3 - 13 %
	B - 0.02 %
	Cu-EDTA - 0.004%
	Fe-DPTA - 0.14%
	Fe-EDDHA - 0.01%
	Mn-EDTA - 0.033%
	Mo - 0.003%
	Zn-EDTA - 0.021%

P was 0.193 watt. Therefore, available pump size in the market that can be used for this NFT system is Kintons 101 pump of 5 watts.

Length of butterhead lettuce leaf and cherry tomato stem's height in S shaped pipe

The result revealed that there were variations in lengths of butterhead lettuce and cherry tomato plants according to the treatments. These values of lengths of plant were obtained at intervals of 7 days of transplanting (7 DAT) with the help of a measuring tape. Comparison of plant lengths at the harvesting stages for both crops can be viewed in *Figure 4*. In the case of butterhead lettuce, treatment T3 had the highest length measurement (33.20 cm) followed by treatment T2 with the length of 26.95 cm and treatment T1 had the lowest average length of leaf of the butterhead lettuce plant (16.06 cm). These were significant differences between treatments T2 and T3. The variation in lengths of the leaf may be due to the effect of light. For the cherry tomato planting, treatment T2 had the highest length measurement (217.20 cm) followed by treatment T3 with the length of 215.10 cm and treatment T1 had the lowest average length of leaf (212.20 cm). There were no significant differences between all the treatments. This shows that growing media of coco fibre had significant impact compared to other growing media in contributing to the increment of butterhead lettuce leaf's length, the key indicator of good harvest for the butterhead lettuce planting. For the cherry tomato planting,

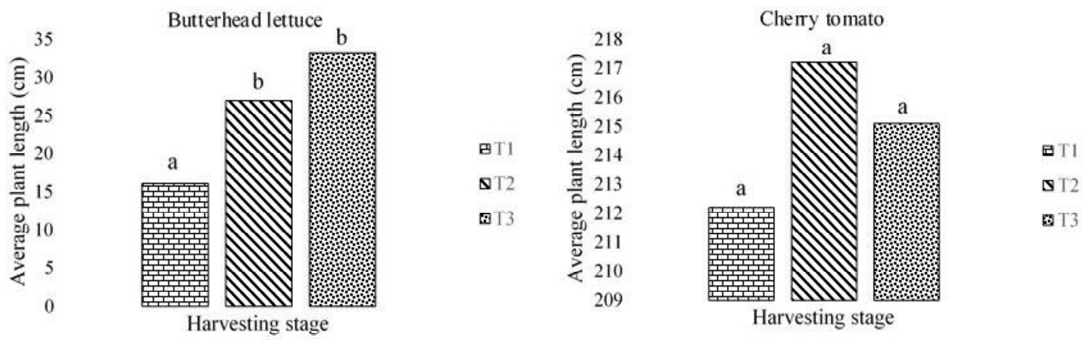


Figure 4 Bar diagram showing effect of different growing media on butterhead lettuce length and cherry tomato plant length at harvesting stage in S shape pipes at harvesting stage.
Note: Means separation in each bar diagram followed by the same letter are not significantly different at p = 0.05.

growing media of clay pebbles had positive impact in increment of the plant lengths which was crucial in contributing towards producing more fruits of cherry tomato due to availability of more spurs on the stem to produce the fruits (Sanchez-Del Castillo *et al.*, 2014).

pH and EC values of hydroponic solution

The pH level differed according to different plant requirement, although generally many plants desire a slightly acid growing environment. For butterhead lettuce a pH range of 5.5 to 6.5 is preferable, though most plants can still endure in an environment with a pH of between 5.0 to 7.5 (Grant, 2016). As shown in *Figure 5*, according to our observation it was found that the ideal pH for butterhead lettuce for higher yield with heavy mass was 6.2. The water pH rate should be maintained to ensure that the plants grow adroitly (Anderson *et al.*, 2017). Similar to this study, plant test was carried out on green mustard. The required pH rate range for green mustard was around 6.0 to 7.5 (Saaid *et al.*, 2015). Thus, for butterhead lettuce the favourable EC range is from 0.8 to 2.0 mS per metre, in spite of the fact that most plants can still persevere in an environment with EC of between 0.8 to 1.2 mS per metre. As shown in *Figure 6*, clay pebbles had higher EC values followed by perlite and coco fibre respectively. In fact, optimum EC values of about 1.48 mS per metre for the butterhead lettuce planting with clay pebbles as growing media shows higher yield with heavy mass compared to other growing media.

The suggested pH for vegetables such as tomato ranges from 5.5 - 6.5. As shown in *Figure 5*, the ideal pH value for the cherry tomato planting was 6.3. For a perfect building up, the fertiliser nutrient content for cherry tomato plants should range in pH of 5.5 to 6 with an EC of 2.0 to 5.0 mS per metre. The device picked to screen pH of hydroponics plan depends on molecule specific cathodes. Structure of EC and pH, was introduced in the UPVC pipe (6 x 8 x 20 mm). This NFT system design provides better development of building structure, thus upgrade course of activity for cherry tomato plants able to run an EC of 2.0 to 5.0 mS per metre as demonstrated in *Figure 6*. Cherry tomato that used growing media of coco fibre shows higher EC reading, followed by clay pebbles and perlite shows the lowest EC values. The ideal EC values for cherry tomato arrangement plan was inside the range of 1.8 to 3 mS per metre and according to the

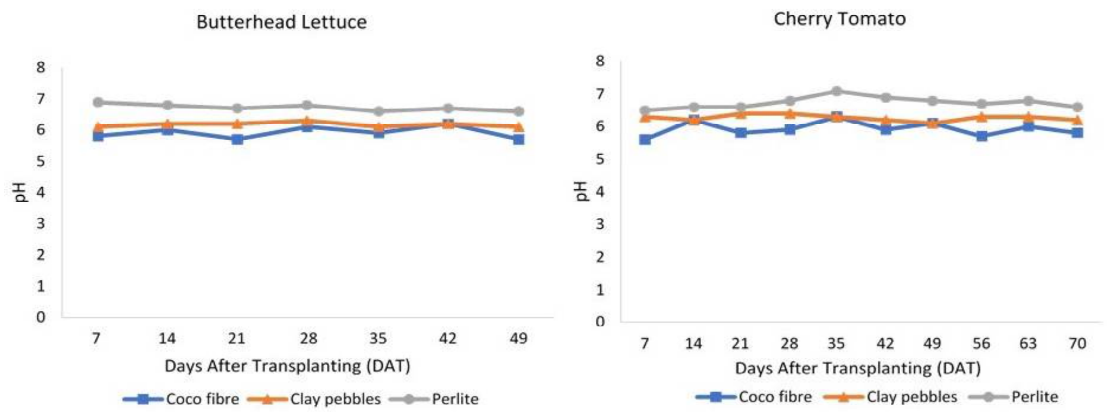


Figure 5 Average pH of hydroponic solution recorded at every 7 DAT until harvesting stage

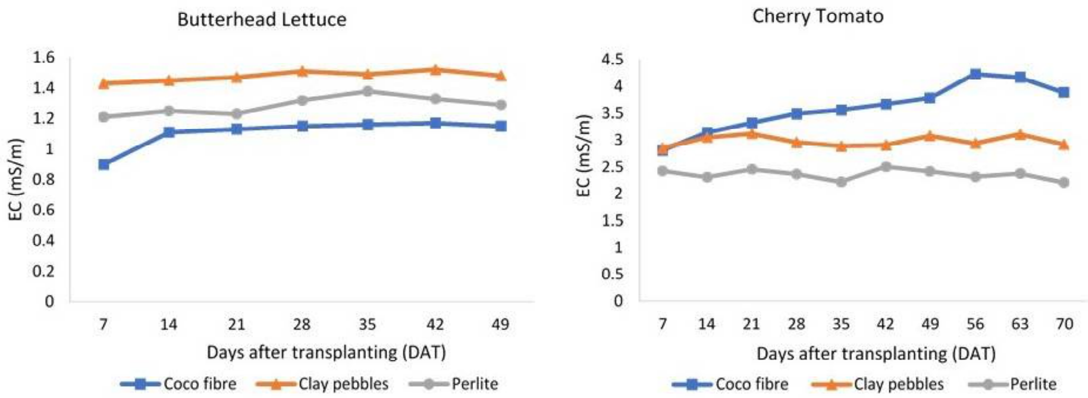


Figure 6 Average EC of hydroponic solution recorded at every 7 DAT until harvesting stage

experiment, cherry tomato planting that used clay pebbles as growing media showed EC values at average range of 2.98 mS per metre and produced higher total count of tomato with heavy weight compared to other growing media (Velazquez *et al*., 2013).

Crop yield

Average yield (g) for both crops are shown in *Figure 7*. Total yield of butterhead lettuce planting was found to be highest when clay pebbles media (200.13 g) was used and showed significant differences compared to the other growing media. The yield on coco fibre media was (175.92 g) and perlite media had the lowest yield (109.12 g). While total yield for cherry tomato planting was almost similar, the treatment that used clay pebbles media (28.36 g) had highest yield and was significantly different to other growing media. This was followed by growing media of perlite with total yield of 25.81 g and coco fibre media had the lowest in production of cherry tomato with total

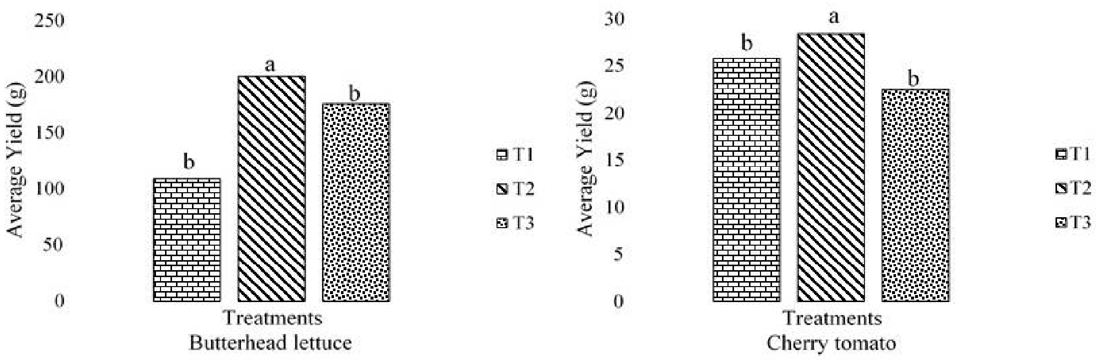


Figure 7 Average yield (g) of butterhead lettuce leaves and cherry tomato plant based on different growing media at harvesting stage.

Note: Means separation in each bar diagram followed by the same letter are not significantly different at $p = 0.05$.

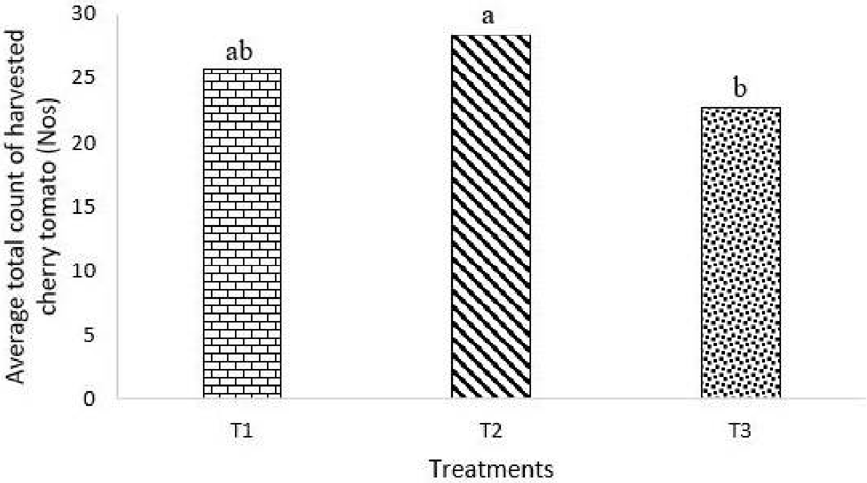


Figure 8 Average *total count of harvested cherry tomato based on different growing media at harvesting stage.*
Note: Means separation in each bar diagram followed by the same letter are not significantly different at $p = 0.05$.

yield of 22.53 g.

Average total count for the final harvest of cherry tomato fruits is shown in *Figure 8.* Total count for cherry tomato planting show that treatment using clay pebbles media (28.4) had the highest tomato count and was significantly different to that from other growing media. This was followed by growing media of coco fibre with total number of 25.7 and perlite media had the lowest number with total amount of 22.8 cherry tomato. This shows that clay pebbles have better ability in retaining and reducing the leaching of the nutrients elements and improve the ability in NFT hydroponic to produce better yield and quality of butterhead lettuce and cherry tomato (Grant 2016; Dorais *et al.,* 2001).

CONCLUSION

On the basis of results of this study the following conclusions are drawn:

- The design and S-shape UPVC pipe system developed for hydroponic system proved to be an acceptable technology for the cultivation of butterhead lettuce and cherry tomato under net protected condition with limited space requirements.
- The pH and EC of the solution in hydroponic system was maintained between 5.5 to 6.5 and 0.8 to 5.0 ds per metre respectively. From our observation, the optimum pH for both crops to have yield with heavy weight and cherry count was between 6.2 and 6.3 while for optimum EC was found around 1.48 mS per metre for butterhead lettuce and 2.98 mS per metre for cherry tomato.
- It was found that growing media of clay pebbles had the highest yield (g) for both crops. This medium led to cherry tomato having the longest stem length that became the main factor for high production of cherry tomato planting i.e.

higher number of tomatoes.

- Coco fibre media contributed to growth and length of the butterhead lettuce leaf compared to the other growing media

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