EFFECT OF GROWING MEDIA ON GROWTH AND YIELD OF TOMATO IN ROOF TOP AQUAVEGECULTURE SYSTEM

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF GROWING MEDIA ON GROWTH AND YIELD OF TOMATO IN ROOF TOP AQUAVEGECULTURE SYSTEM"** *submitted to the Department of Horticulture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (M.S.)*** *in* ***HORTICULTURE,*** *embodies the results of a piece of bona fide research work carried out by* ***MD. SOJIB HOSSAIN,*** *Registration. No.* ***10-04179*** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information as has been availed of during the course of this investigation has duly been acknowledged.

Dated: JUNE, 2017
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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

An experiment was conducted during the period of October 2016 to February 2017 on the rooftop of Agriculture Faculty at Sher-e-Bangla Agricultural University, Dhaka-1207. Treatment as three levels of growing media i.e. M_1=Broken stone, M_2= 50% khoa + 50% broken stone, M_3= Khoa; and two levels of variety i.e. V_1= Exotic tomato line (AVRDC), V_2= BARI Tomato 15. Result indicated that almost all of the parameters varied significantly. The highest plant height (78.67 cm), maximum number of fruits (31.01) and highest fruit yield (858.67 g $plant^{-1}$) were obtained from M_2. Whereas it was the lowest in M_1. Considering the varietal performance, the highest plant height (81.00 cm), maximum number of fruits (33.11) and highest fruit yield (840.11 g $plant^{-1}$) were obtained from V_2. The treatment combination M_2V_2 gave the best performance in terms of growth and yield parameters. So, 50% khoa + 50% broken stone and BARI Tomato 15 could be used to cultivate tomato in roof top aquavegeculture system.

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BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
Co	Cobalt
CV%	Percentage of coefficient of variance
cv.	Cultivar
DAE	Department of Agricultural Extension
DAS	Days after sowing
^{0}C	Degree Celsius
et al	And others
FAO	Food and Agriculture Organization of the United Nations
g	gram(s)
ha^{-1}	Per hectare
HI	Harvest Index
kg	Kilogram
Max	Maximum
mg	Milligram
Min	Minimum
MP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Not significant
%	Percent
SRDI	Soil Resources and Development Institute
AEZ	Agro-Ecological Zone

CHAPTER I

INTRODUCTION

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INTRODUCTION

Aquavegeculture is an amazingly productive way to grow vegetables, herbs and fruit while providing added benefits of fresh fish as a safe, healthy source of protein. On a larger scale, it is a key solution to mitigate food insecurity, climate change, groundwater pollution and the impact of overfishing on our oceans. This is a water saving technology and would be appropriate for Bangladesh which is highly vulnerable to climate change impact. Due to soilless, clean water and regulated condition in aquaveeculture system, it is believed that the flavor and quality of herbs and vegetables would be much higher than those grown in the field (Estim and Mustafa, 2010).

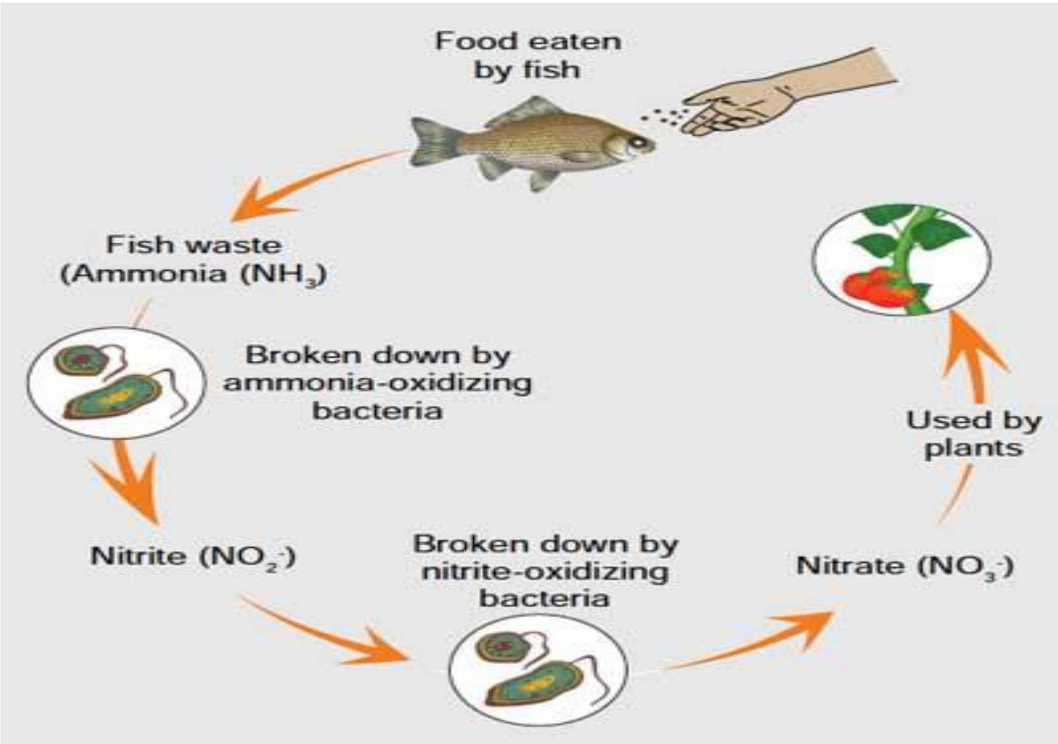

Figure A. Working principle of aquavegeculture system

Tomato (*Lycopersicon esculentum*) is an excellent fruit-vegetable which are widely known for their outstanding antioxidant content, including of course, their often times rich concentration of lycopene. Aquavegeculture is a bio-integrated system. The waste produced by fish serves as perfect manure for plants and water cleaned in this way is made available to fish through recirculation (Racoky *et. al*., 2004). With the right choice of fish and plant species, aquavegeculture serves as a model of environmentally compatible and sustainable food production system (Chand *et. al*., 2006). Because aquavegeculture is energy-efficient, prevents discharge of waste into the environment, provides organic fertilizer to plants (rather than synthetic chemicals), reuses the waste water through biofiltration and ensures higher production of food per unit area through multiple cropping. It deserves to be treated as a working model of green technology (Mustafa *et al*., 2010). Tomato has an excellent combining ability to grow with fish in aquavegeculture system. Right choice of growing media may also increase the growth and yield of tomato.

Fisheries sector plays a very important role in Bangladesh economy. The sector contributes about 4.43% to GDP, 2.73% to the total export earnings (DoF, 2012). The sector can be broadly classified into three categories: open water fisheries, culture fisheries (aquaculture) and marine fisheries. The annual fish production in 2010-2011 was over 30.62 lakh metric tons from which, capture fisheries contributed 34.43%, culture fisheries 47.71% and 17.84% marine fisheries (DoF, 2012). So, aquaculture plays an important role in the fish production compared to the area of capture fisheries in our country. Due to meet up country's demand and export to foreign countries aquaculture is practiced extensively in the country. Ponds, tanks and ditches comprise 3500 km^2 and brackish water aquaculture 1900 km^2 to the total area of the country (DOF, 2012). For the aquaculture pressure, ground water level is decreasing day by day as fish farmers are mostly depend on ground water for fish culture. Also, agricultural land in our country is reducing day by day.

Now-a-days food safety is one of the major problems of the world. Farmers used various chemicals and fertilizers in food production which make the food toxic and dangerous for human health. The various diseases and physical problems are arising due to consuming these contaminated foods. In such situation aquaponics may be an excellent way to become sustainable food production. Aquaponics system provides organic food with no health hazards.

Aquaculture plays a crucial role as a source of animal protein for billions of people worldwide and supports the livelihoods of 10–12% inhabitants in the world (FAO, 2012). In 2011, global aquaculture production was increased to 62.7 from 59 million tons in 2010 of which 89% came from Asia. Demand for fish is leaping with the population increase in Bangladesh for the last three decades (FAO, 2012) which has increased the land use competition between agricultural crop production and fish farming (Ahmed and Garnett, 2011). Moreover, land gets shrinking, reckless population growth, manmade environmental pollution and impact of climate change creates new challenges to the country's agriculture sector that has emphasized to integrate crop and fish farming like aquaponics (Salam *et al*., 2014). The word Aquaponics is the marriage of 'Aquaculture' and 'Hydroponics' and at the same time it shares some common attributes of both the systems, which is something far more developed and eventually, unique from either of them. Aquaponics is a typical urban agriculture, a combination of two different cultures: aquaculture or farming fish, and hydroponics or crop production in soilless substrate. It is the symbiotic relation between the fish and vegetables where fish provides fertilizer to the plants, in return plants help to purify the wastewater as they use the nutrients where the fish live in (Roe and Midmore, 2008). The aquaponics has control on farming systems which can protect the crops from diseases, heavy rains, floods, drought and hailstones. The aquaponics is an environmental friendly and sustainable food production system (*Salam et al*., 2013).

Roof gardens are most often found in urban environments. Plants have the ability to reduce the overall heat absorption of the building which then reduces energy consumption. The primary cause of heat build-up in cities is insolation, the absorption of solar radiation by roads and buildings in the city and the storage of this heat in the building material and its subsequent re-radiation. Plant surfaces however, as a result of transpiration, do not rise more than 4–5 °C above the ambient and are sometimes cooler (Ong, 2003). This then translates into a cooling of the environment between 3.6 and 11.3 degrees Celsius (6.5 and 20.3 °F), depending on the area on earth (in hotter areas, the environmental temperature will cool more). The study was performed by the University of Cardiff (Brahic, C. 2007).

A study at the National Research Council of Canada showed the differences between roofs with gardens and roofs without gardens against temperature. The study shows temperature effects on different layers of each roof at different times of the day. Roof gardens are obviously very beneficial in reducing the effects of temperature against roofs without gardens. “If widely adopted, rooftop gardens could reduce the urban heat island, which would decrease smog episodes, problems associated with heat stress and further lower energy consumption (Liu, 2018).

By considering the above information the present research was conducted with the following objectives-

1) To find out the best suited media for roof top under aquavegeculture system.
2) To find out the best suited varieties of tomato for aquavegeculture system in the roof top.
3) To determine the suitability of integrated vegetable fish production system in the roof top.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

There are some published reports on aquaponics, its study and related activities. A short description on the available literature relevant to the present investigation is presented here.

Salam et al. (2014) conduct an experiment on nutrient recovery from fish farming wastewater in aquaponics system for plant and fish integration and found that mean weight gain (%) of tilapia was 926.18 % using spinach (*Ipomoea aquatica*) for 115 days and survival rate was 91.90 %.

Roosta and Hamidpour (2013) reported that, effects of foliar applications of some micro- and macro-nutrients on mineral nutrient content of tomato leaves and fruits were investigated in an aquaponic system in comparison with a hydroponic system. Fourteen days old tomatoes seedlings were transplanted on to growth bed of aquaponic and hydroponic systems. Foliar nutrients application began 30 days after transplantation. Eight treatments were used, untreated control and foliar application at the rate of 250 mL plant^{-1} with 0.5 g L^{-1} potassium sulfate (K_2SO_4), magnesium sulfate ($MgSO_4$ $7H_2O$), ferrous (Fe)- ethylenediamine-N,N′-bis (EDDHA), manganese sulfate ($MnSO_4$ H_2O), boric acid (H_3BO_3), zinc chloride ($ZnCl_2$), and copper sulfate ($CuSO_4$ $5H_2O$). Foliar application of potassium (K), magnesium (Mg), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) increased their corresponding concentrations in the leaves of aquaponic-treated plants. On the other hand, foliar spray of K, Fe, Mn, Zn, and Cu caused a significant increment of applied element concentrations in the fruits of hydroponic-grown plants. These findings indicated that foliar application of some elements can effectively alleviate nutrient deficiencies in the leaves of tomatoes grown on aquaponics.

Ingrid (2013) conducted a study on how water quality changes over time in a small scale re-circulating system where waste water from smolt production was used to grow lettuce for commercial use. The treatment effect of lettuce on different solutions was tested and corresponding lettuce yield was evaluated. Phosphorus, potassium, manganese, zinc and copper decreased significantly in most of the waste water solutions, these elements are all nutrients for plants, hence they are most likely taken up by the lettuce. Despite the uptake of essential nutrients, the lettuce did not grow optimally and had several signs of distress symptoms both during and at the end of the experiment. Magnesium and chloride increased significantly due to evaporation from the reservoirs. Together with the high concentration found for sodium in all the wastewater solutions it was believed that the lettuce was exposed to toxic levels of salt. This was a possible explanation to why the lettuce did not grow sufficiently. Considering optimal conditions for lettuce growth the pH of the waste water solutions was too high, and the electrical conductivity was higher than recommended. One of the challenges with integrated production of salmon smolt and plants is the high content of salt in the waste water. The salt is necessary in most cases for production of salmon smolt but inhibits plant growth. If the plant is able to treat the water for nutrients and other waste products, without being depressed by the salt, re-use of the water is possible in addition to getting a marketable product.

Jason and Austin (2013) conducted an experiment to compare and contrast the growth of tomatoes, beans, and pea plants in an aquaculture medium with fish and no fish by monitoring the changes in ammonia, pH, nitrate, phosphate, temperature, and salinity of water overtime. Results showed that there were no significant growth differences by height of peas, tomatoes, and beans when growing between aquaponics vs. traditional soil. However, there were significant differences between growing plants in aquaponics vs. the control hydroponic with water only. Data confirmed at day 7 that nitrates at its peak and as ammonia decreased, caused the aquaponics plants to grow rapidly. Thus, the experiment confirmed a correlation between nitrate and plant growth.

Michael (2012) investigated an innovative approach to recapture nutrients from post-consumer food waste by converting it into a pelletized fish food for a bench-scale aquaponics system. Two treatments, each with three replicated aquaponics systems, were constructed to determine the effect of using food waste for fish and lettuce production. Food waste pellets had significantly more fat, less mineral content, and similar protein and fiber content compared with commercial fish feed. Nile tilapia (*Oreochromis niloticus*) had significantly greater specific growth rate (SGR) and food consumption rates on the commercial diet than those on the food waste diet. The feed conversion ratio (FCR) between treatments was similar. Lettuce biomass production was significantly reduced in food waste systems. Palatability of post-consumer food waste seemed to be the most significant factor to overcome.

Dunn (2012) stated that modern aquaponics is a viable resource to sustainability that combines aquaculture (growing fish and plants in a controlled environment) and hydroponics (growing plants without soil). The system relies on fish waste to provide organic food and nutrients to help the plants grown; in turn, the plants clean, filter, and recycle the water back to the fish creating a symbiotic relationship.

Jessica (2012) stated that in aquaponics system water containing fish waste is pumped to the plants, where nutrient water is absorbed and utilized for plant growth. Alternatively, plants provide filtering of the water of excess nutrients that can be toxic to the fish. This experiment tested two food crops (lettuce and radish) grown in three different medias (soil, coconut fiber, gravel) in two separate aquaponics systems Nutrient Film Technique (NFT) and Floating Raft (FR) to determine which media maximized plant growth in both systems. Each plant was planted and replicated in each pot (3X) and differing media (3X) as seed and grown for 8 weeks (NFT) and 5 weeks (FR). Growth rates were measured by recording heights weekly and biomass (mg) at the end of the experiment. Both lettuce and radishes had the greatest growth in soil in both systems.

Combining hydroponics and aquaculture allows the chemical nutrients needed for hydroponic plant growth to be replaced with fish wastes that might otherwise be discharged and cause potential environmental degradation. As a sustainable food production technology, aquaponics can play a role in increasing the availability of nutritious food in present and future food systems. Small to medium-scale aquaponics systems require very little space and can be used in homes, backyards, basements, balconies and rooftops to increase personal and community food security (Bernstein, 2011).

Rakocy (2011) stated that tilapia is an ideal choice of fish for aquaponics. They are very hardy fish species in that they grow and reproduce quickly and are readily accepted in the world market.

Rana *et al*. (2011) studied on searching of low-cost eco-tech for the reclamation of municipal domestic wastewater, tomato plants (*Lycopersicum esculentum*) were cultivated on the floating bed of pulp-free coconut fiber over four different concentrations of wastewater (25%, 50%, 75% and 100%) and groundwater as control, in 10 L plastic bucket for two months. The study revealed that PO_4-P was removed by 58.14–74.83% with maximum removal at 50% wastewater. More than 75% removal of NO_3-N was observed in all treatments. Both COD and BOD were reclaimed highest at 100% wastewater by 61.38% and 72.03%, respectively. Ammonium-N concentration was subsided below the toxic level in all the treatments. The population of coliform bacteria (*Escherichia coli*) was reduced to 91.10–92.18% with maximum efficiency at 100% wastewater. Growth performance was observed relatively better at 100% wastewater. Crop production as the value addition of this technology was also recorded maximum at 100% wastewater.

Normala *et al*. (2010) noted that fish culture could be carried out in aquaponics system over extended periods, mint stocks had to be harvested at shorter intervals, preferably every fortnight, and replaced by fresh stocks. Keeping the same plant in the system led to fall in biomass and would impair the water quality since nutrient uptake in unhealthy plants was slower and might even cease if the culture would continue. In fact, shortage of certain nutrients such as iron, calcium and potassium in soilless culture might be occurred. While most of the nitrogen and phosphate requirements were met from the fish waste, there could be deficiency of potassium and some micronutrients, including iron and magnesium.

Philippe (2010) conducted a study is to investigate the techno-economic feasibility of operating an aquaponics farm in South Africa. The study finds that currently aquaponics in South Africa is hindered by a number of constraints that result in it being a high-risk venture with meager returns on investment. However, the study shows that if an aquaponics system were designed, built and managed correctly, it could theoretically be an economically viable venture.

Steve and Rinehart (2010) stated that fish raised in re-circulating tank require good water quality. Water quality testing kits from aquaculture supply companies are fundamental. Critical water quality parameters include dissolved oxygen, carbon dioxide, ammonia, nitrate, nitrite, pH, chlorine and other characteristics. The stocking density of fish, growth rate of fish, feeding rate and volume and related environmental fluctuations can elicit rapid changes in water quality; hence, constant and vigilant water quality monitoring is essential.

Endut *et al*. (2009) recommended that aquaponics systems were designed to provide an artificial, controlled environment that optimizes the growth of fish and soil-less plant, complete control over water quality, the production schedule and the fish product, while conserving water resources. Five different water flow rates (0.8, 1.6, 2.4, 3.2, and 4.01/min) were tested in order to relate 5 nutrients removal, water quality and plant growth. It was found that the highest plant growth rate was at 1.6 1/min and that high growth rates and yields were generally seen when the major growth limiting nutrient nitrogen, was delivered as a combination of ammonium and nitrate. In terms of fish growth rate, there were no significant differences in the feed conversion ratio (amount of food given vs. weight gained) at various at flow rates. The-results showed that the aquaponics system removed BOD (47-65%), total suspended solids (67-83%), NH_3-N (64-78%), $N0_2$-N (68-89%), and demonstrated positive correlation with flow rates. NO_3 removal ranged from 42-65%, but decreased proportionately with flow rate after 1.6 l/min. It was suggested that the higher flow rates resulted in less contact time between nitrate and denitrifying bacteria, thus decreasing the system's denitrifying performance. Total phosphorous concentration ranged between 42.8% and 52.8%, and again had highest removal rates at 1.61/min. It was concluded that both plant growth and fish production were better at a flow rate of 1.61/min.

Endut *et al.* (2009) conducted a research to find out the effect of flow rate on water quality parameters and plant growth of water spinach *(Ipomoea aquatica)* in an aquaponic re-circulating system. The effect of five different water flow rates was tested in order to relate nutrients removal, water quality and plant growth. The results showed that the aquaponic re-circulating system removed 5-day biochemical oxygen demand of 47–65%, total suspended solids of 67–83%, total ammonia nitrogen (64–78%), and nitrite-nitrogen (68–89%), and demonstrated positive correlation with flow rates. Total phosphorus and nitrate-nitrogen removal rates varied from 43% to 53% and 42% to 65%, respectively, and were negatively correlated with flow rates. It was found that all flow rates were efficient in nutrient removal and in maintaining the water quality parameters within the acceptable and safe limits for growth and survival of fish.

Jason (2009) found in aquaponics system under the specified environmental conditions 5 kg m^{-3} of Nile tilapia (*O. niloticus*) fed 2% of their body weight daily yields on average 4.7 kg m-2 of lettuce (*L. sativa* cv. Rex) in 35 days. There was no significant difference ($p \leq 0.05$) in biomass or chlorophyll concentration index in lettuce (*L. sativa* cv. Rex) grown with aquaponics water. The aquaponics solution generated equal biomass and chlorophyll concentration indexes compared to the hydroponic solution. Aquaponics water plus supplementation can yield *L. sativa* cv. Rex with equal biomass accumulation and chlorophyll concentration indexes compared to hydroponics lettuce. Nutrients added to the aquaponics system consisted of iron, manganese, and zinc. These nutrient concentrations became depleted in the aquaponics water over time and were not 12 replenished via the fish feed. Dolomite was added to the aquaponics system every two weeks to increase the buffering capacity of the water and maintain optimal pH levels. Aquaponics lettuce had similar nutrient composition to hydroponic lettuce. One head of L. sativa cv. Rex (176.75 g) will assimilate approximately 5.96 grams of nitrogen (3.38% per dry gram lettuce).

One kilogram of fish will yield 6.4 lettuce heads (1,128 grams) and fixate 38.13 grams of nitrogen.

Andreas and Junge (2008) conducted an experiment where Aubergine, tomato and cucumber cultures were established in the LECA filter and nutrient removal rates calculated during 42-105 days. The highest nutrient removal rates by fruit harvest were achieved during tomato culture: over a period of greater than 3 months, fruit production removed 0.52, 0.11 and 0.8 gm-2d-l for N, P and K in hydroponic and 0.43, 0.07 and 0.4 gm-2d-l for N, P and K in aquaponics system. In aquaponics system, 69% of nitrogen removal by the overall system could thus be converted into edible fruits.

Graber *et al*. (2008) recommended that there were several benefits to the owner of a backyard aquaponics system. Firstly, the waste produced by the fish was recovered by the plant instead of being expelled to the environment. Water exchange is minimized since the growing medium and plants act as bio-filters, cleaning and returning the clean water to the fish tank. The surface area of the grow bed provided the area for bacterial growth and was related to the treatment capacity of the system. The treatment capacity had a unit of mass removal per unit time.

Hu *et al*. (2008) carried out an experiment to treating the eutrophic water with water spinach *(Ipomoea aquatica)* in deep flow technique (DFT) system. After a 48-h exposure to the plant, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total suspended solids (TSS) and chlorophyll *a* in the effluent were reduced by 84.5, 88.5, 91.1, and 68.8%, respectively, and the removal of nutrients (total nitrogen and total phosphorus) varied between 41.5 and 75.5%. Vitamin C and NO_3-N concentrations in plants grown in the eutrophic water were significantly different from those grown in a standard nutrient solution.

While fruiting crops of all kinds are successfully grown in aquaponic systems, they are mostly cultivated by hobbyists growing for consumption or by researchers. Because these plants have longer harvesting times, they are better suited to growth in areas that have a longer growing season such as the tropics where growing can be carried out all year long. Melons, tomatoes, okra, peppers and corn are all popular fruiting crops crown in aquaponic systems (Nelson, 2008).

Li *et al.* (2007) conducted a research to investigate the use of water spinach (*Ipomoea aquatica* Forsk.) with N^+ ion-beam implantation for removal of nutrient species from eutrophic water. The mutated water spinach was grown on floating beds, and growth chambers were used to examine the growth of three cultivars of water spinach with ion implantation for 14 days in simulated eutrophic water at both high and low nitrogen levels. The specific weight growth rates of three cultivars of water spinach with ion implantation were significantly higher than the control, and their NO_3-N and NH_4-N removal efficiencies were also greater than those of the control.

Tyson *et al*. (2007) stated that nitrifying bacteria is inhibited below a pH of 6.5, with an optimum pH of 7.8 depending on bacterial species and temperature.

Nile tilapia in addition of hydroponic culture with 10 basil /m^2 gave the best significant ($P<0.05$) fish production 20.1 kg /m^3 in a recirculating aquaculture system (Kamal, S. M. 2006)

Rakocy *et al.* (2006) reported that, when choosing a crop to cultivate, the grower's objective should be taken into account first and foremost. If the objective of the venture is to turn a profit, as it is with commercial scale systems, then crops that have a high market value and short harvesting time will be more appropriate. These include herbs such as basil, chives, cilantro, and parsley whose harvest times are between 25 and 40 days. Other leafy green vegetable of this nature are Swiss chard, Pak Choi, Chinese cabbage, collard and watercress, which in addition to the aforementioned advantages, also experience less pest problems than fruiting plants. Lettuce is the most grown crop in aquaponics due to both its short harvesting time (3-4 weeks) and high demand in western diets. Annual projected yield of basil for the aquaponic system is 5.34 mt for batch production and 5.01 mt for staggered production whereas on field production was 7.7 mt. Fruiting vegetables have a longer growing cycle and often have more pest and disease problems associated with them, but typically receive higher prices at markets.

Diver (2006) stated that the fish species was an important consideration when setting up an aquaponics system. Trout, perch, Arctic char, tilapia and bass were just a few of the warm and cold-water fish suitable for re-circulating aquaculture systems. However, most commercial aquaponics systems in North America were based on tilapia.

Fitzsimmons (2006) stated that tilapia is a hardy fast-growing fish with a low protein requirement making them a primary target for aquaponics re-circulating systems. Tilapia fish are omnivorous and have a relatively low protein requirement in comparison to other carnivorous fish.

Rakocy *et al*. (2006) stated that in developed countries concerns about pollution issues had raised interest in aquaponics system as a valid option to get rid of aquaculture wastes through the production of high value vegetables.

Rakocy *et al*. (2006) stated that in an aquaponics system, fish are fed a high-protein diet. The fish then process the feed for growth and excrete waste that is high in potentially toxic nitrogen compounds, including ammonia (NH_3), through their gills. These compounds are processed into nitrate (NO_3) by beneficial bacteria naturally occurring in the system. The plants then utilize the produced nitrates for growth. Additionally, the plants absorb these compounds, which are harmful to the fish, from the water, serving as a bio-filter, thereby reducing the needs for active mechanical filtration and diligent water quality management. The plants also reduce the need to replace and alter water for the fish-growing system, and the fish provide a constant supply of biologically available nutrients for the plants. These two biological processes can eliminate the need for expensive nutrient management systems employed in conventional hydroponics and induce plant growth more effectively.

Saleh (2006) studied on aquaponics production of Nile tilapia (*Oreochromis niloticus*) and bell pepper (*Capsicum annuum* L.) in re-circulating water system. In this experiment nile tilapia (*Oreochromis niloticus*) and bell pepper (*Capsicum* *annuum* L. 'Godeon') were cultured for 180 days in a closed system containing 1160 L of water for each unit. Six units were used with three treatments (all three treatments were in duplicated) to determine the effect of the integration 2-3 between plant number /m to fish density (100 fish /m) on fish performance. 2 Each unit consists of 500 L fish rearing tank, hydroponic tank (2 m), filter and 2 sumps. Treatments were T_1 (fish culture with 10 plant/m), T_2 (fish culture with 2-15 plant/m) and T_3 fish culture without plant (control). Water quality suitable for fish production was maintained by aeration, mechanical and biological filtration, hydroponics vegetable production unit and the addition of make-up water. Fish metabolites and wasted feed served as nutrient sources for pepper 2 productions. The results showed that T_1 (fish culture with 10 plants /m) gave the best significant ($P<0.05$) fish production 20.1 kg / m, followed by T_2 (fish 2 culture with 15 plants /m) 17.95 kg / m and the lowest ($P<0.05$) was T_3 fish 3 culture without plant (control) 16.3 kg / m. Also, T_1 (fish culture with 10 plants 2 2 /m) was higher in average yield of marketable bell pepper 11.34 kg fai 2 ($P>0.05$) than T_2 (fish culture with 15 plants /m).

Wilson and Brian (2006) studied on comparison of three different hydroponic sub-systems (gravel bed, floating and nutrient film technique) in an Aquaponics test system. Murray Cod, Maccullochella peelii (Mitchell), and Green Oak lettuce, (*Lactuca sativa*), were used to test for differences between three hydroponic subsystems, Gravel Bed, Floating Raft and Nutrient Film Technique (NFT), in a freshwater Aquaponics test system, where plant nutrients were supplied from fish wastes while plants stripped nutrients from the waste water before it was returned to the fish. The Murray Cod had FCR’s and biomass gains that were statistically identical in all systems. Lettuce yields were good, and in terms of biomass gain and yield, followed the relationship Gravel bed > Floating > NFT, with significant differences seen between all treatments. The NFT treatment was significantly less efficient than the other two treatments in terms of nitrate removal (20% less efficient), whilst no significant difference was seen between any test treatments in terms of phosphate removal. In terms of dissolved oxygen, water replacement and conductivity, no significant differences were observed between any test treatments. Overall, results suggest that NFT hydroponic sub-systems are less efficient at both removing nutrients from fish culture water and producing plant biomass or yield than Gravel bed or Floating hydroponic sub-systems in an Aquaponics context.

Lin *et al.* (2005) stated that since the concept of aquaponics implied use of fish waste as a major source of nutrient for the plant production, the nutrient balance in the fish feed is crucial for the plant. The requirements for potassium were different for plants and for fish. Fish meal, the major component of the fish feeding formulations is not always rich in potassium. The measured level of potassium in the fish effluent was 10 folds less than that of calcium and 5 folds less than sodium in the beginning of the experiment. The recommended Ca: K (calcium: potassium) ratio for hydroponic production of most crops was between 2:1 and 1:1. Ca (calcium) and Na (sodium) interfere with K (potassium) uptake. The increased level of these elements can cause severe K starvation. Thus, the preliminary observations in this aquaponics system revealed an intrinsic nutrient unbalance in the system based on fish feeding feeds prepared with plant nutrients.

Savidov, M. (2005) stated that here are also several varieties of plant species that can be grown in aquaponics systems. These fall into three main categories based on the solution conductivity factor (CF) in which the plants perform best. Group 1 comprises plants with high CF and includes tomato and eggplant. Group 2 plants have medium CF and include lettuce, basil, and cucumber. Group 3 consists of plants with low CF and includes watercress.

Al-Hafedh, Y. S., Alam, A. and Beltagi, M. S.(2008) stated that fish waste and accumulated feed builds up in the system. Nitrogen, phosphorous, and organic matter accumulate in high quantities in aquaculture systems. Nitrogenous wastes are produced when nitrogen in the form of ammonia is excreted by the fish. Ammonia is the byproduct of protein synthesis by the fish. Nutrient levels from fish aquaculture are suitable for plant growth and can be manipulated by increasing fish biomass and feed rate or by increasing the protein levels in the feed.

Ghaly *et al*. (2004) stated that high-value vegetable crops, such as tomato, lettuce, cucumber and sweet basil, had cultured in hydroponic media. It was more desirable to grow high priced produce such as herbs to get the best profit per unit area of aquaponics bed.

Rakocy *et al*. (2004) stated that aquaponics is the most efficient food production system in terms of amount of product produced per volume of water. It takes approximately 500 liters of water to produce $100 of product (fish and lettuce), whereas producing cattle take more than 100 times as much water to produce a $100 of product.

Rakocy *et al*. (2004) developed a commercial scale aquaponics system at the University of Virgin Islands in St. Croix. No major changes in the system had been implemented since 2000, 2002 and 2003, where trials were conducted to evaluate the production of basil and okra. Batch and staggered production of basil in the aquaponics system was compared to field production of basil using staggered production technique. There were four harvests of the basil in batch production with an average yield of 2.0 kg/m^2. Initially there were savoir of nutrients; however, by the fourth harvest evidence of nutrient deficiency was obvious. The cropping system was therefore changed to a staggered production to moderate nutrient uptake. In the staggered production trial, the plants were cut once (1.2 Kg/m^2) and allowed to re-grow for a final second harvest (2.4 Kg/m^2). A second trial was conducted where the staggered production procedure was followed for basil seedlings that were planted in an adjoining field. The yield was 0.6 Kg/m^2. Three varieties of okra seedlings were planted (North-South, Annie Oakley, and Clemson Spineless) and grown hydroponically at a low density (2.7 $plants/m^2$) and high density.

Savidov (2004) stated that the integration of fish and plant systems can potentially reduce the amount of water used per kilogram of food produced.

Wilson (2004) suggested that in terms of plant yield and nutrient stripping, Nutrient Film Technique (NFT) might be as much as 20% less efficient than gravel beds and floating rafts because in gravel bed and raft systems the plant roots were 100% in contact with the water column whereas, in NFT, only up to 50% of the root mass was in contact with the water. It stood to reason that with up to 50% less contact area, plans grown in NFT would grow a bit slower and, therefore, remove a bit less nutrient.

Britto *et al.* (2002) stated nitrate is taken up by the plant at better rates than ammonia which can be toxic to plants. Ammonia concentrations at elevated levels can inhibit nutrient uptake in plants by altering the ionic capacity of the water medium. Depending on plant species sensitivity symptoms of ammonia toxicity appear with external ammonia concentrations above 0.1 - 0.5 Smol/L.

Timmons *et al*. (2002) stated that re-circulating aquaculture was an environmentally responsible alternative to fishing and virtually eliminates by-catch waste which occurs in wild fisheries. Water discharge/replacement requirements was 5% to 10 % of re-circulating water volume per day makes these systems subject to discharge restrictions due to concerns with environmental waste management. RAS can produce more fish per liter of water than other types of aquaculture systems therefore reducing water used.

Watanabe *et al*. (2002) stated that tilapia can withstand low dissolved oxygen levels but optimal growth occurs with levels greater than 2 mg / L.

Popma and Masser (1999) stated that Continuous supply of adequate amounts of aeration to fish and the bacteria bio-filter in a re-circulating system is essential to its proper operation. Tilapia needs at least 5 mg/L of dissolved oxygen for optimal growth, and if concentrations fall below 2.5 mg/L they have significant growth retardation.

Prinsloo *et al*. (1999) showed that nitrification transforms 93% to 96% of nitrogenous fish wastes into nitrate.

Villaverde *et al*. (1997) stated that for Nitrosomonas and Nitrobacter, the optimum pH is within 7.2 to 8.2, whereas nitrification is inhibited below a pH of 5.

Timmons (1996) stated that the conceptual aspect of aquaponics is to balance the nutrients within a given system. Nutrients are delivered to the system through an input source, in this case fish feed. Protein content in the feed dictates the amount of nitrogen that is available to the plants after the fish assimilate and process the nutrients. The density of fish, protein content in the feed, and the feeding rate drive the nutrient loading of the system. Balancing the amount of nutrients produced from the fish system with the nutrient requirements of the plants can lead to optimized resource utilization and system productivity.

Tilapia can tolerate poor water quality, wide temperature and salinity ranges, low dissolved oxygen levels and elevated ammonia concentrations compared to other fish species grown in commercial farming operations (Masser *et al*., 1992).

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The chapter deals with the methodology, which was conducted to achieve the objective of the study. It includes a short description of location of the experiment, selection of research materials, materials and selection of experimental design and analytical tools. The fish tank preparation, vegetable bed preparation, tomato seedlings selection, selection of fish species, stocking of fish, measuring water quality parameters, fish sampling, tomato plant growth and tomato and fish production were recorded and analyzed to achieve the objective of the study.

3.1 Experimental site

The experiment was conducted on the roof of academic building of Sher-e-Bangla Agricultural University, Dhaka. The experiment was carried out during the period from October 2016 to February 2017. The location of the site in 23°74" N latitude and 90°35" E longitude with an elevation of 8.2 meter from sea level (Anon, 2009). The location of the experimental site was represented in appendix I.

3.2 Climate

The experimental site is located in subtropical region where climate is characterized by heavy rainfall during the months from April to September (Kharif season) and scanty rainfall during rest of the month (Rabi season). The maximum and minimum temperature, humidity rainfall and soil temperature during the study period are collected from the Sher-e-Bangla Mini weather station (Appendix II).

3.3 Plant materials

The tomato cultivar i.e. BARI Tomato15 and Exotic tomato line (AVRDC) seed was used as a test crop.

3.4 Experimental design and treatments

The experimental model comprises of a fish holding tank of 250 liter and six food grain plastic containers. Plastic containers were used in holding three different media each having three replications. Three types of media were used in this experiment that was 50% khoa with 50% broken stone, khoa and broken stone. Each bed size was 2.5 × 2.0 ft for all treatments. The media containing containers were indicated as per the treatment. An aerator with two aerators ports was used in fish tank to supply dissolved oxygen. The waste water from the fish tank was irrigated to the vegetable bed by a 12 watt submersible water pump. The tank water was aerated with a 10 watt air pump fitted with two air stones.

Treatments

The two factorial experiments was laid and that was

Factor A: Tomato variety

a) V_1= Exotic tomato line (AVRDC)
b) V_2=BARI Tomato 15

Factor B: Growing media

a) M_1= Broken stone
b) M_2= 50% Khoa + 50% Broken stone
c) M_3= Khoa

Treatment combinations: V_1M_1, V_1M_2, V_1M_3, V_2M_1, V_2M_2, V_2M_3

3.5 Fish tank preparation

An experimental plastic tank, with the volume of 250 liter was used for fish culture. The size of the tank was 1.10×0.90 m. This tank was bought from local market and prepared for stocking and rearing of fish fingerlings.

3.6 Stocking of fish

Fingerlings were collected and feeding was done that is discussed in section 3.7 and 3.8.

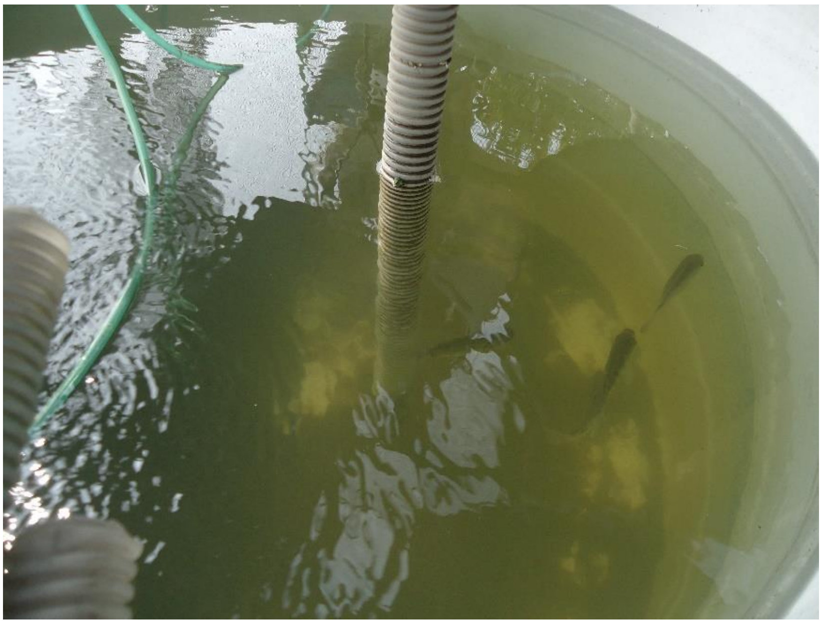

Plate 1. Stocking of fish

3.7 Collection of fingerlings

Healthy tilapia fingerlings were collected for the experiment. They were collected from the hatchery of Fisheries Department of Sher-e-Bangla Agricultural University. Fingerlings (length 5.5±0.65 cm and weight 4.34±1.25 g) were brought to the experimental site with proper handling and transportation. They were transported with oxygenated polythene bag. Disinfection of fingerlings was carried out before stocking. Thirty five (35) fingerlings were stocked in the fish tank.

3.8 Feeding

Commercial floating feed containing 30% protein was used to feed the fish. The feed was collected from the Krishi market, Mohammadpur, Dhaka. The feed was supplied once daily at the rate of 10% of fish body weight distributed.

3.9 Sampling of fish

Fish sampling was carried out at 15 days interval. Scoop net was used to catch the fish during sampling. Ten fishes were caught randomly from the tank. Then length and weight of individual fish was measured carefully. Weight was taken with a balance and length with a measuring scale. All the data were recorded in a notebook. Immediately after recording the length and weight the fry was released in the respective tank.

Plate 2. Data collection of fish

3.10 Fish growth parameter

The following parameters were used to evaluate the growth of fish such as length gain (cm), weight gain (g), percent weight gain, food conversion ratio (FCR), survival rate (%) and production of fish (kg/tank).

3.10.1 Length gain

Length gain was calculated using the following formula:

Length gain (cm) = mean final length (cm) – mean initial length (cm)

3.10.2 Weight gain

Weight gain was calculated using the following formula:

Weight gain (g) =mean final weight (g)- mean initial weight (g)

3.10.3 Percent weight gain

This is fairly straight forward measure of overall increase in the mean body weight over a time period.

$$\text{Weight gain}=\frac{\text{Mean final weight}-\text{Mean intial weight}}{\text{Mean intial weight}}\times 100$$

3.10.4 Survival rate

The survival rate of fish was calculated from the number of fish of each pieces harvested at the end of experiment. The survival rate was estimated by the

Following formula

$$\text{Survival rate}=\frac{\text{Number of fish harvested}}{\text{Number of fish stocked}}$$

3.10.5 Fish production

The production of fish was determined by multiplying the mean increased weight (g) of fish by the total number of caught fish. Finally, thirty (30) fish were harvested (Table 11).

3.11 Bed Preparation for tomato culture

Seeds of BARI Tomato15 were collected from the Bangladesh Agricultural Research Institute (BARI) and Exotic tomato line (AVRDC) from Taiwan. Tomato seedlings were raised in the seedbed situated on a relatively high land at Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka. The size of the seedbed was 3 m x l m. The soil was well prepared with the help of spade and made into loose friable and dried mass to obtain fine tilth. All weeds and stubbles were removed and 5 kg well rotten cowdung was applied during seedbed preparation. The seeds were sown on 10 October, 2016 and after sowing, seeds were covered with light soil to a depth of about 0.6 cm. Heptachlor 40 WP was applied @ 4 kg/ha around each seedbed as precautionary measure against ants and worm. The emergence of the seedlings took place within 5 to 6 days after sowing. Necessary shading by banana leaves was provided over the seed bed to protect the young seedlings from scorching sun or heavy rain. Weeding, mulching and irrigation were done from time to time as and when required and no chemical fertilizer was used in the seedbed.

3.11.1 50% khoa and 50% broken stone

Khoa and broken stone were collected locally for the experiment. Same amount of khoa and broken stone was mixed properly by using spade. Then canes were filled with these mixed bedding materials.

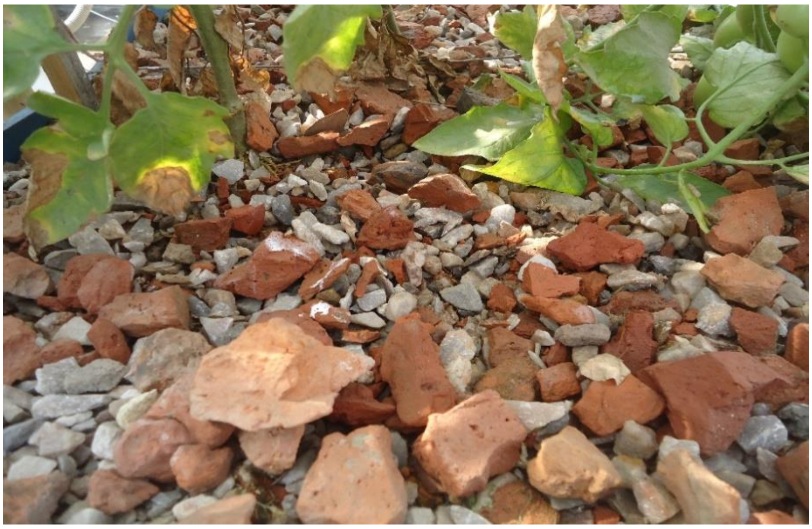

Plate 3. 50% khoa and 50% broken stone

3.11.2 Khoa

Khoa were collected locally for the experiment. Then canes were filled with these bedding materials.

Plate 4. Khoa

3.11.3 Broken stones

The broken stones were collected locally for the experiment. Then canes were filled this bedding materials.

Plate 5. Broken stones

3.12 Planting of tomato seedling

After putting the media in the plastic cane, tomato seedling were collected from the Horticulture Farm of Sher-e-Bangla Agricultural University and planted on it. The tomato seedlings were 30 days old that used for plantation in the experiment. Four seedlings were planted in four corners of each of the bed. Plantation was done 11 November 2016.

3.13 Start watering the vegetable beds

After plantation watering was started. Only fish tank water was used for watering. Watering was done by using a porous PVC pipe. Watering pipe was cleaned regularly to provide maximum waste water supply. A motor was used for watering of plant from fish tank to beds. In night time waste water supply was stopped. No fertilizer was used in the vegetable beds. Initially 10-12 days was required to slowly grow denitrifying bacteria in the beds and nitrification started in full swing. After that time plants grew well. When plants grew into larger size bamboo sticks were used as support. Plants were tied with the sticks using rope.

3.14 Harvesting

When the green fruits were in marketable condition then they were harvested.

Plate 6. Plant at harvesting stage

3.15 Plant growth data collection

The experiment was conducted to compare the tomato plant growth as well as tomato production in different media. The data of following parameters were collected-

a) Plant height (cm)
b) Number of leaves plant^{-1}
c) Number of branches plant^{-1}
d) Foliage coverage (cm^2)
e) Length of internode (cm)
f) Stem diameter (cm)
g) Chlorophyll content
h) Number of cluster plant^{-1}

i) Number of flower $plant^{-1}$
j) Number of fruit $plant^{-1}$
k) Individual fruit weight (g)
l) Individual fruit length (cm)
m) Individual fruit diameter (cm)
n) Fruit yield $plant^{-1}$ (kg)

3.16 Data collection procedure

3.16.1 Plant height

Plant height was taken at three times and measured in centimeter from ground level to tip of the main stem from each plant of each treatment and mean value was calculated.

3.16.2 Number of leaves per plant

Total number of leaves was counted at three times from each plant of the treatment and mean value was calculated.

3.16.3 Number of branches per plant

Total number of branches was counted at three times from each plant of the treatment and mean value was calculated.

3.16.4 Length of internode

Length of internode was taken by measuring tape in centimeter.

3.16.5 Stem diameter

Stem diameter was taken by measuring tape in centimeter. Diameter of stem was measured at the middle portion of stem from each plot and their average was taken.

3.16.6 Chlorophyll content

A segment of 20 mg from middle portion of leaf was used for chlorophyll analysis. Chlorophyll content was measured using SPAD chlorophyll meter.

3.16.7 Number of cluster per plant

Number of cluster per plant was counted from first cluster was appearance. Number of cluster was recorded for each treatment.

3.16.8 Number of flower per plant

Number of flower per plant was counted from the each of the treatment. The total number of flower per plant was counted and average number of fruit was recorded.

3.16.9 Number of fruit per plant

Number of fruit was counted from first harvest stage to last harvest. The total number of fruits per plant was counted and average number of fruit was recorded.

3.16.10 Individual fruits weight

To estimate individual fruit weight, six fruits in every plant and every harvest were considered. Thus, the average individual fruit weight was measured.

3.16.11 Fruit length and girth

Fruit length and girth was taken by measuring tape in centimeter. Girth i.e. breath of fruit was measured at the middle portion of fruits from each plant and their average was taken by slide calipers. Average length of same fruits was also taken.

3.16.12 Yield of fruits

To estimate yield, all the four plants in every plot and all the fruits in every harvest were considered. Thus, the average yield per plant was measured.

3.17 Statistical analysis

The recorded data on different parameters were statistically analyzed using Statistix 10 software and mean separation was done by Tukey HSD test at 5% level of probability.

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

This chapter represents the result and discussions of the present study. Summary of mean square values of different parameters are also given in the appendices section.

4.1 Plant height

Plant height increased gradually with the advancement of growth stage and it was up to the harvest. The tallest plant was obtained from the V_2 (44.22 cm, 73.22 cm and 81.00 cm at 30, 60 days after transplanting (DAT) and during harvest, respectively) over the variety V_1 (Figure 1 and Appendix III). This might be due to the genetic variation among varieties where maximum nutrient uptake by V_2 from aquavegeculture system. Because nutrient uptake and vegetative growth as well as reproductive development depend on the candidate gene of tomato (Xia *et al*., 2012).

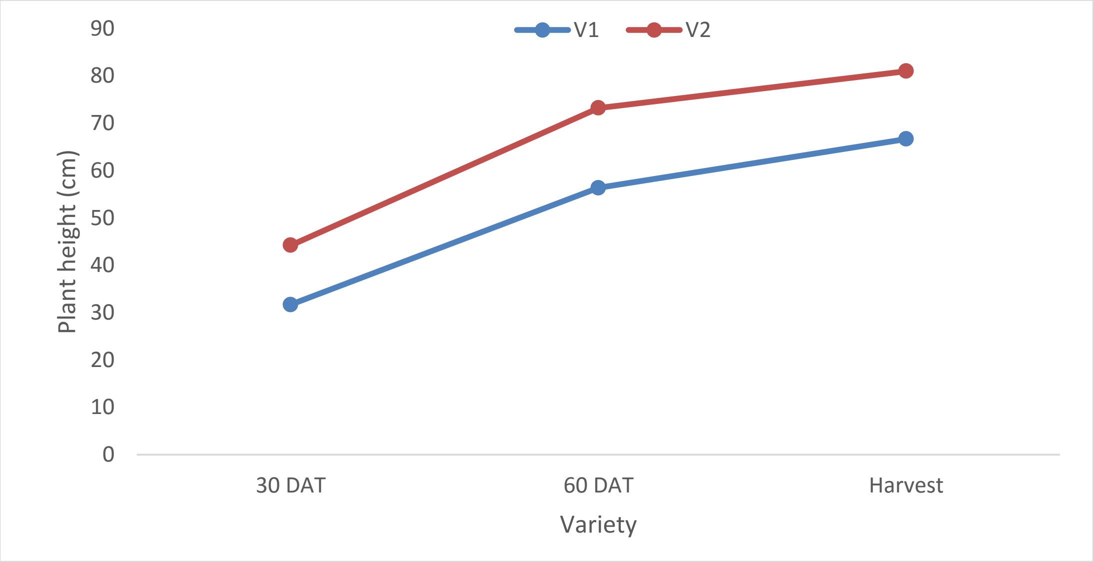

Figure 1. Effect of variety on plant height of tomato

DAT= Days after transplanting; V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15

Plant height showed significant variations for the different growth media. Data revealed that media M_2 produced the tallest plant (42.00 cm, 71.33 cm and 78.67 cm at 30, 60 DAT and at harvest, respectively) over M_1 (34.50 cm, 58.50 cm and 69.17 cm at 30, 60 DAT and during harvest, respectively) (Figure 2 and Appendix III). This fact that, media M_2 facilitated proper aeration and minimum water loss through evaporation and helped plant to uptake of nutrient from aquavegeculture system for proper growth of plant. The finding agreed with the findings of Salam *et al.* (2014), Roosta and Hamidpour (2013), Ingrid (2013), Jason and Austin (2013), Michael (2012), Dunn (2012), Jessica (2012), Bernstein (2011), Rakocy (2011), Normala *et al*. (2010).

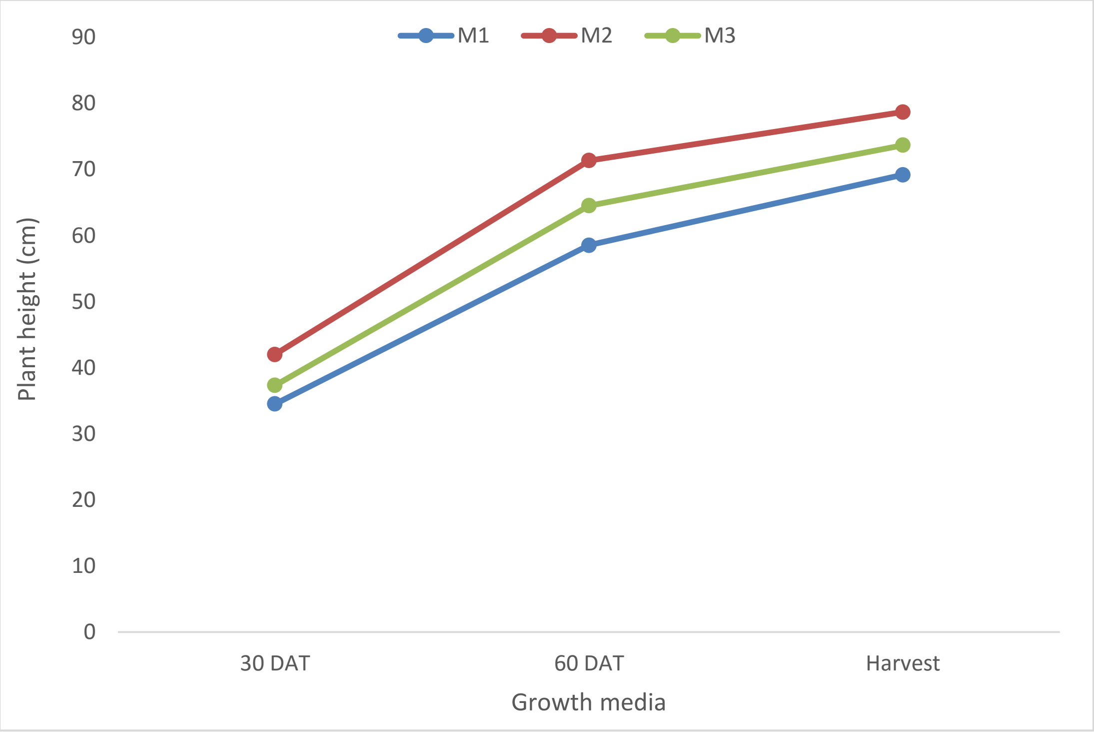

Figure 2. Effect of growth media on plant height of tomato

DAT= Days after transplanting; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

A significant variation was observed in terms of plant height due to interaction of variety and growth media at all sampling dates except at 30 DAT and harvest time (Table 1 and Appendix III). The highest plant height was recorded from V_2M_2 interaction compared to others. Here the plant height ranges from 28.01 cm to

48.12 cm, 48.99 cm to 78.66 cm and 62.30 cm to 86.11 cm at 30, 60 DAT and during harvest, respectively.

Table 1. Interaction effect of variety and growth media on plant height

Treatments	Plant height (cm) at		
	30 DAT	**60 DAT**	**Harvest**
V_1M_1	28.01	48.99 f	62.30
V_1M_2	36.33	64.01 d	71.33
V_1M_3	31.12	56.23 e	66.23
V_2M_1	41.05	68.33 c	76.04
V_2M_2	48.12	78.66 a	86.11
V_2M_3	43.66	73.00 b	81.13
SE (±)	NS	0.46	NS
CV (%)	-	0.88	-

DAT= Days after transplanting; V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

4.2 Number of leaves plant^{-1}

Number of leaves of tomato increased gradually with the advancement of growth stage and up to the harvest. The maximum number of leaves (12.84, 29.22 and 45.21) was obtained from the V_2 compared to the V_1 (8.33, 22.77 and 33.00) at 30, 60 DAT and during harvest, respectively (Figure 3 and Appendix IV). The fact that the genetic variation among varieties where maximum nutrient uptake by V_2 from aquavegeculture system. Because nutrient update and vegetative growth as well as reproductive development depend on the candidate gene of tomato (Xia *et al*. 2012).

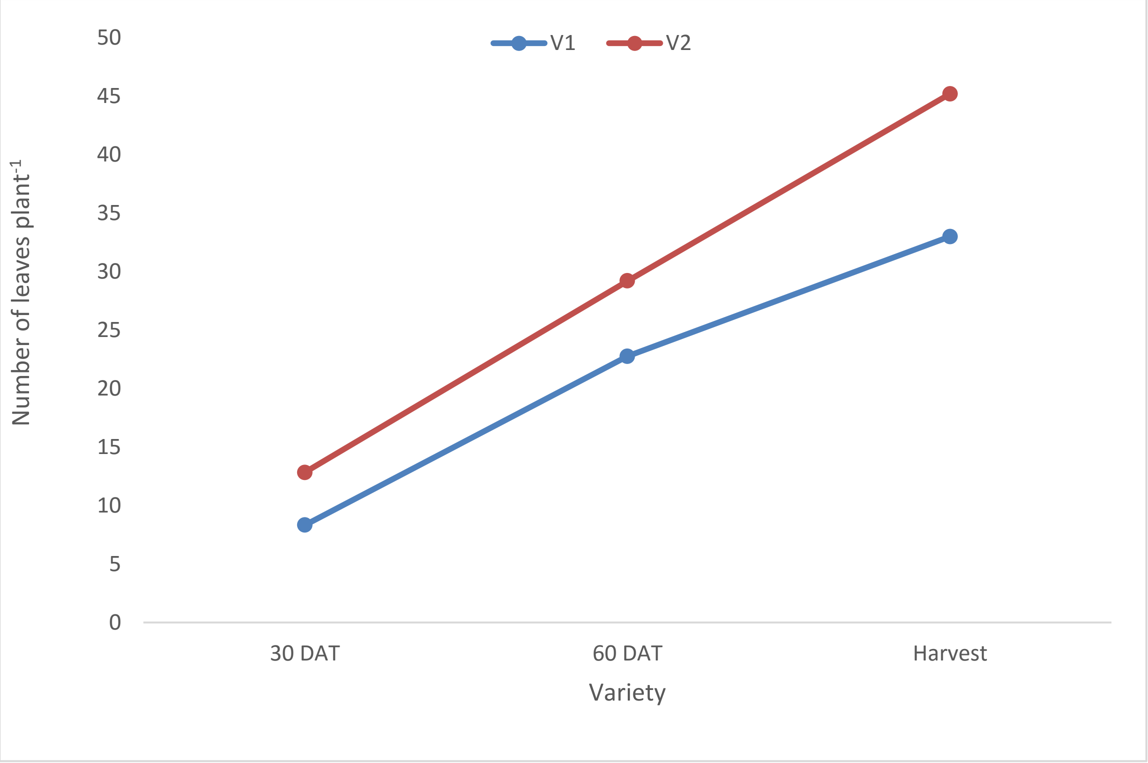

Figure 3. Effect of variety on number of leaves plant^{-1} of tomato

DAT=Days after transplanting; V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15

Number of leaves of tomato varied significantly due to the effect of different growth media (Figure 4 and Appendix IV). The data revealed that M_2 produced the maximum number of leaves (12.58, 28.67 and 43.06 at 30, 60 DAT and during harvest, respectively) and M_1 produced the minimum number of leaves (8.78, 23.83 and 35.11 at 30, 60 DAT and during harvest, respectively). This might be due to that, media M_2 facilitated proper aeration and helped plant to uptake of nutrient from aquavegeculture system for proper growth of plant. The aquavegeculture system also provided adequate nutrient for proper growth and development of plant. Andreas and Junge (2008), Graber *et al*. (2008), Hu *et al*. (2008), Nelson (2008), Li *et al.* (2007), Tyson *et al*. (2007), Rakocy *et al.* (2006), Diver (2006), Fitzsimmons (2006), Rakocy *et al*. (2006), Saleh (2006) also reported the similar finding.

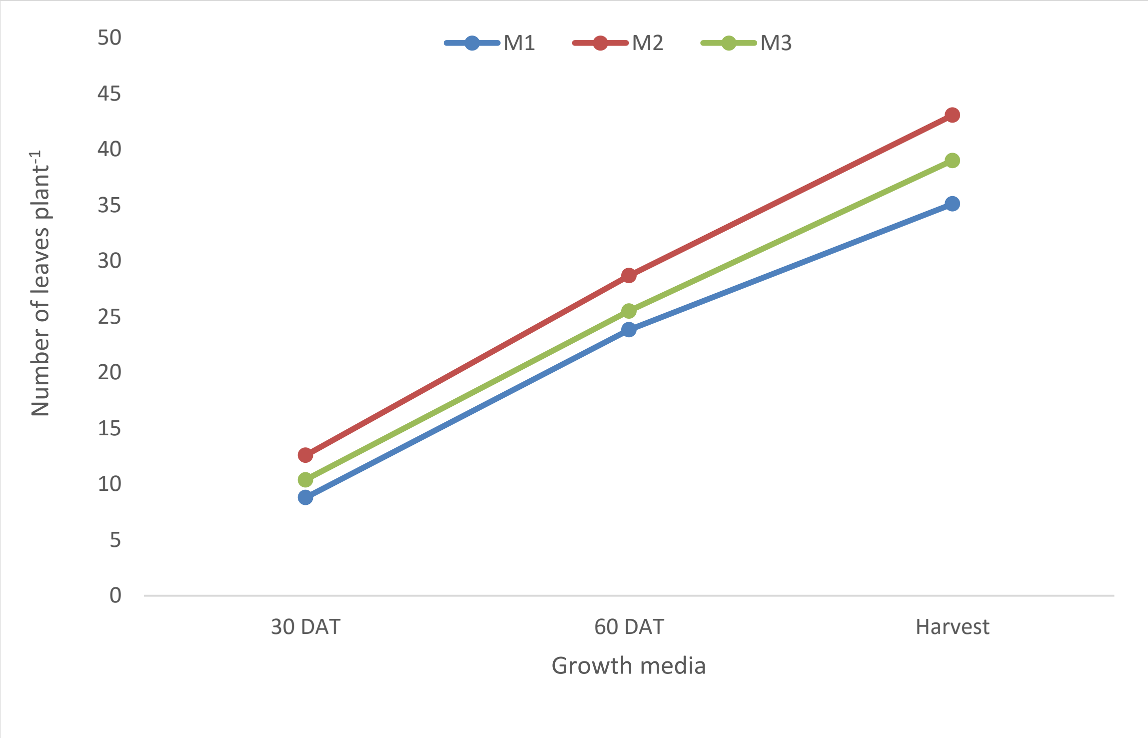

Figure 4. Effect of growth media on number of leaves plant^{-1}

DAT= Days after transplanting; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

The interaction effect of variety and growth media produced the maximum number of leaves at all growth stages and at harvest (Table 2 and Appendix IV). Also, there was no significant effect of this interaction. The interaction V_2M_3 produced the maximum number of leaves (15.00, 32.00 and 49.23 at 30, 60 DAT and during harvest, respectively) while V_1M_1 produced the minimum number of leaves (6.40, 20.33 a d 29.01 at 30, 60 DAT and during harvest, respectively).

Table 2. Interaction effect of variety and growth media on number of leaves

Treatments	Number of leaves at		
	30 DAT	**60 DAT**	**Harvest**
V_1M_1	6.40	20.33	29.01
V_1M_2	10.16	25.32	37.03
V_1M_3	8.43	22.66	33.11
V_2M_1	11.17	27.30	41.22
V_2M_2	15.00	32.00	49.23
V_2M_3	12.33	28.33	45.06
SE (±)	NS	NS	NS
CV (%)	-	-	-

DAT= Days after transplanting; V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

4.3 Number of branches plant^{-1}

Number of branches plant^{-1} of tomato showed statistically significant variations of tomato (Table 3 and Appendix V). From the experiment it was observed that variety V_2 helped to produce maximum number of branches plant^{-1} of tomato (4.34) while the minimum number of branches were observed in variety V_1 (3.33). This might be due to the genetic variation among varieties where maximum nutrient uptake by V_2 from aquavegeculture system. Because nutrient update and vegetative growth as well as reproductive development depend on the candidate gene of tomato (Xia *et al*. 2012).

Mean number of branch showed a wide range of variations where highest number of branch plant^{-1} (4.88) was recorded from the media M_2 while M_1 produced lowest number of branches (2.76) compare to others media (Table 3 and Appendix V). Probably, media M_2 facilitated proper aeration and helped plant to uptake of nutrient from aquavegeculture system for proper growth of plant. The aquavegeculture system also provided adequate nutrient for proper growth and development of plant. Ingrid (2013), Jason and Austin (2013), Bernstein (2011), Rakocy (2011), Rana *et al*. (2011), Philippe (2010), Graber *et al*. (2008), Hu *et al*. (2008), Nelson (2008), Li *et al.* (2007), Diver (2006), Fitzsimmons (2006), also reported the similar finding.

Table 3. Effect of variety and growth media on number of branches plant-1, foliage coverage and length of internode

Treatments	Number of branches	Foliage coverage (cm^2)	Length of internode (cm)
V_1	3.33	46.65	4.33
V_2	4.34	61.11	5.03
SE (±)	0.047	0.204	$1.648E^{-03}$
CV (%)	2.61	1.25	0.07
M_1	2.76	49.00	4.20
M_2	4.88	59.17	5.14
M_3	3.85	53.51	4.69
SE (±)	0.057	0.25	$2.018E^{-03}$
CV (%)	2.61	1.25	0.07

DAT= Days after transplanting; V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

The interaction effect of variety and growth media had produced the positively significant number of branches (Table 4 and Appendix V). The interaction V_2M_2 produced the maximum number of branches (5.36) while V_1M_1 produced the minimum number of branches (2.37) compared to other combination.

Table 4. Interaction effect of variety and growth media on number of branches, foliage coverage and length of internode

Treatments	Number of branches	Foliage coverage (cm^2)	Length of internode (cm)
V_1M_1	2.37 d	31.12 f	3.70 f
V_1M_2	4.40 b	42.23 d	4.89 c
V_1M_3	3.23 c	36.03 e	4.40 e
V_2M_1	3.16 c	49.22 c	4.70 d
V_2M_2	5.36 a	61.33 a	5.42 a
V_2M_3	4.47 b	53.00 b	4.99 b
SE (±)	0.81	0.46	$2.854E^{-03}$
CV (%)	2.61	1.25	0.07

DAT= Days after transplanting; V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

4.4 Foliage coverage

Significant variation for foliage coverage of tomato were observed due to the varietal treatment (Table 3 and Appendix V). The variety V_2 produced highest foliage coverage (61.11 cm^2) over the other variety. The fact that the genetic variation among varieties where maximum nutrient uptake by V_2 from aquavegeculture system. Because nutrient update and vegetative growth as well as reproductive development depend on the candidate gene of tomato (Xia *et al*. 2012).

The foliage coverage of tomato was influenced significantly due to different levels of growth media (Table 3 and Appendix V). The highest foliage coverage

($59.17\ cm^2$) was produced from the media M_2 and the minimum foliage coverage ($49.00\ cm^2$) was observed from the M_1 treatment. This fact that, media M_2 facilitated proper aeration for bacterial growth and multiplication and helped plant to uptake nutrient from aquavegeculture system for proper growth of plant. The aquavegeculture system also provided adequate nutrient for proper growth and development of plant. Jason and Austin (2013), Michael (2012), Dunn (2012), Jessica (2012), Bernstein (2011), Rakocy (2011), Philippe (2010), Steve and Rinehart (2010), Endut *et al*. (2009), Andreas and Junge (2008) also reported the similar finding.

There was a significant impact of interaction effect of variety and growth media observed for foliage coverage (Table 4 and Appendix V). The highest foliage coverage was given by V_2M_2 compared to others combination.

4.5 Length of internode

The length of internode was significantly influenced by the both of varieties (Table 3 and Appendix V). The variety V_2 produced the highest value of length of internode (5.03 cm) compared to V_1 (4.33 cm). This might be due to the genetic variation among varieties where maximum nutrient uptake by V_2 from aquavegeculture system. Because nutrient update and vegetative growth as well as reproductive development depend on the candidate gene of tomato (Xia *et al*. 2012).

The growth media were showed highly significant effect in length of internode of tomato (Table 3 and Appendix V). The highest value of length of internode (5.14 cm) were produced by M_2 while the lowest value of this trait was produced by M_1 (4.20 cm). Probably, media M_2 facilitated proper aeration and helped plant to uptake of nutrient from aquavegeculture system for proper growth of plant. The aquavegeculture system also provided adequate nutrient for proper growth and development of plant. Salam *et al.* (2014), Rakocy (2011), Rana *et al*. (2011), Normala *et al*. (2010), Philippe (2010), Steve and Rinehart (2010), Endut *et al*. (2009), Andreas and Junge (2008), Graber *et al*. (2008), Hu *et al*. (2008), Nelson (2008), Li *et al.* (2007), Tyson *et al*. (2007), also reported the similar finding.

Interaction effect of variety and growth media showed significant effect only at harvest (Table 4 and Appendix V). The ranges of length of internode was 2.30 cm to 5.23 cm, 3.63 cm to 5.14 cm and 3.70 cm to 5.42 cm at 30 DAT, 60 DAT and harvest time, respectively. The interaction V_2M_2 produced the highest value of length of internode (5.23 cm, 5.14 cm and 5.42 cm) at all sampling dates.

4.6 Chlorophyll content

The chlorophyll content of tomato plant showed statistically significant variations (Figure 5 and Appendix VI). From the data it was observed that variety V_2 helped to produce maximum chlorophyll content of tomato plant (55.00) while the minimum chlorophyll content was observed in variety V_1 (45.33). This might be due to the genetic variation among varieties where maximum nutrient uptake by V_2 from aquavegeculture system. Because nutrient update and vegetative growth as well as reproductive development depend on the candidate gene of tomato (Xia *et al*. 2012).

The recorded data of chlorophyll content showed a wide range of variations where the highest chlorophyll content (54.23) was recorded from the media M_2 while media M_1 produced the lowest value (47.03) compared to other media (Figure 5 and Appendix VI). This fact that, media M_2 facilitated proper aeration and helped plant to uptake nutrient from aquavegeculture system for proper growth of plant. The aquavegeculture system also provided adequate nutrient for proper growth and development of plant. Roosta and Hamidpour (2013), Ingrid (2013), Hu *et al*. (2008), Nelson (2008), Li *et al.* (2007), Tyson *et al*. (2007), Rakocy *et al.* (2006), Diver (2006), Fitzsimmons (2006), Rakocy *et al*. (2006), Saleh (2006) also reported the similar finding.

The interaction effect of variety and growth media had produced the non-significant chlorophyll content of tomato plant (Table 5 and appendix VI). The interaction V_2M_2 produced the maximum chlorophyll content (59.00) while V_1M_1 produced the lowest chlorophyll content (42.03) compared to other combination.

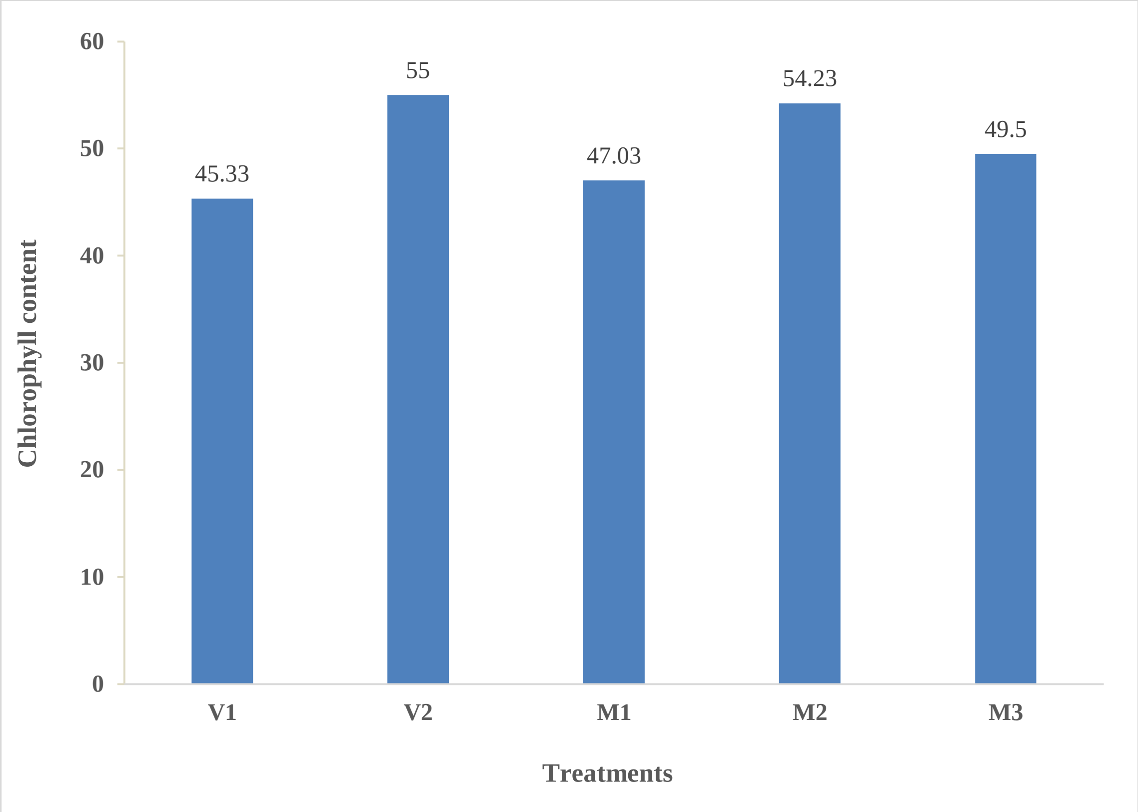

Figure 5. Effect of variety and growth media on chlorophyll content

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

Table 5. Interaction effect of variety and growth media on chlorophyll content

Treatments	Chlorophyll content
V_1M_1	42.03
V_1M_2	49.12
V_1M_3	45.11
V_2M_1	52.23
V_2M_2	59.00
V_2M_3	54.32
SE (±)	NS
CV (%)	-

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

4.7 Number of cluster plant^{-1}

Significant variation was observed for number of cluster plant^{-1} of tomato from the different variety. The variety V_2 produced maximum number of cluster plant^{-1} (Figure 6 and Appendix VI). In this varietal treatment, 20.56 nos cluster plant the was produced by V_2 treatment while 15.78 nos cluster plant the was produced by V_1 treatment. This might be due to the genetic variation among varieties where maximum nutrient uptake by V_2 from aquavegeculture system. Because nutrient update and vegetative growth as well as reproductive development depend on the candidate gene of tomato (Xia *et al*. 2012).

The number of cluster plant^{-1} was significantly influenced by different growth media in aquaculture system. The treatment M_2 produced the maximum number of cluster plant^{-1} and minimum number of cluster was recorded from M_1 treatment (Figure 6 and Appendix VI). The cluster number of M_2 treatment was 20.50 and the cluster number of M_1 treatment was 16.16. This might be due to that, media M_2 facilitated proper aeration and helped plant to uptake of nutrient from aquavegeculture system for proper growth of plant. The aquavegeculture system also provided adequate nutrient for reproductive development of plant. Jason and Austin (2013), Michael (2012), Dunn (2012), Jessica (2012), Bernstein (2011), Rakocy (2011), Rana *et al*. (2011), Normala *et al*. (2010), Nelson (2008), Rakocy *et al*. (2006), Diver (2006) also reported the similar finding.

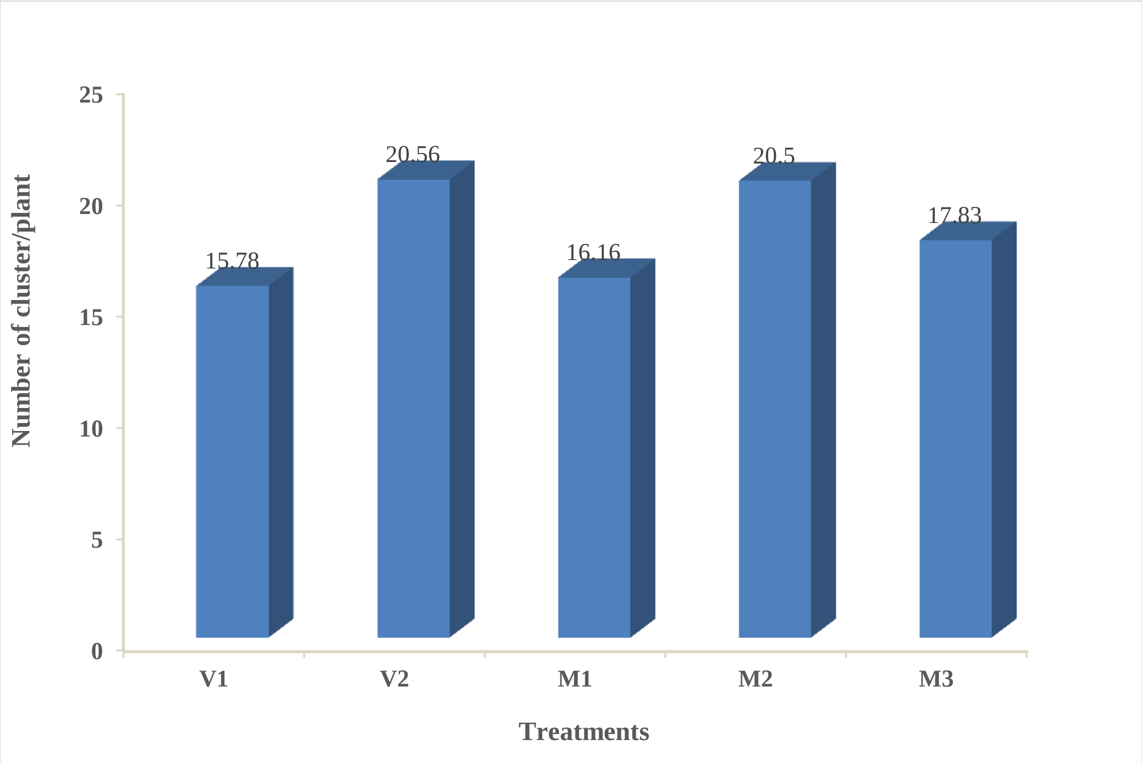

Figure 6. Effect of variety and growth media on number of cluster plant^{-1}

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

There had non-significant impact of interaction effect of variety and growth media on number of cluster plant^{-1} (Table 6 and Appendix VII). The cluster number ranges from 14.04 to 23.16. The maximum number of cluster plant^{-1} was recorded from V_2M_2 combination (23.16 nos) while the minimum number of cluster plant^{-1} was found in V_1M_1 combination (14.04 nos) compared to others.

Table 6. Interaction effect of variety and growth media on number of cluster

Treatments	**Number of cluster plant^{-1}**
V_1M_1	14.04
V_1M_2	18.12
V_1M_3	15.33
V_2M_1	18.32
V_2M_2	23.16
V_2M_3	20.34
SE (±)	NS
CV (%)	-

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

4.8 Number of flowers plant^{-1}

Tomato variety had the significant result on number of flowers plant^{-1} in aquaculture system (Figure 7 and Appendix VII). The variety V_2 produced the maximum number of flowers (63.42) compared to the variety V_1 (46.88). This might be due to the genetic variation among varieties where maximum nutrient uptake by V_2 from aquavegeculture system. Because nutrient update and vegetative growth as well as reproductive development depend on the candidate gene of tomato (Xia *et al*. 2012).

The number of flowers plant^{-1} varied significantly due to influence of different growth media (Figure 7 and Appendix VII). It was noticed that the maximum number of flowers plant^{-1} obtained from M_2 and the minimum number of flowers was observed from M_1 treatment. The fact that, media M_2 facilitated proper aeration and minimum losses of water through evaporation and helped plant in proper flowering. The aquavegeculture system also provided adequate nutrient for reproductive development of plant. Bernstein (2011), Rakocy (2011), Rana *et al*. (2011), Normala *et al*. (2010), Philippe (2010), Steve and Rinehart (2010), Endut *et al*. (2009), Hu *et al*. (2008), Nelson (2008) also reported the similar finding.

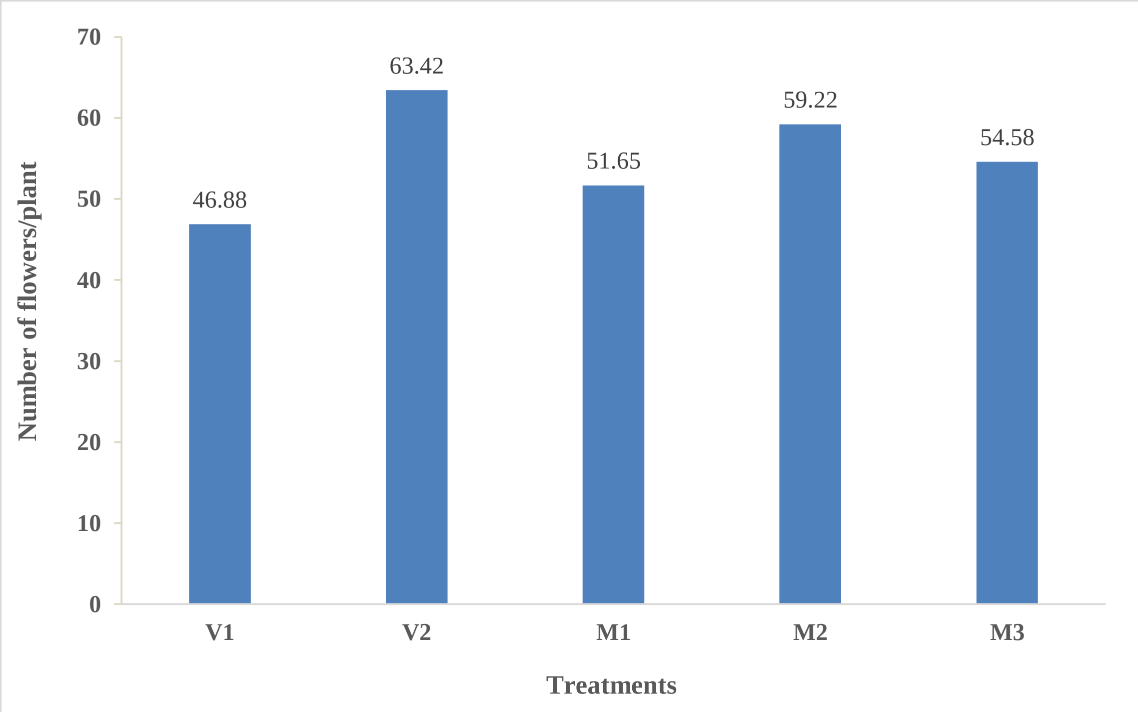

Figure 7. Effect of variety and growth media on number flowers plant^{-1}

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

The number of flowers plant^{-1} significantly varied from the combine effect of variety and growth media. The number of flowers ranges from 43.16 to 67.03 (Table 7 and Appendix VII). In the present study, data showed that V_2M_2 produced the maximum number of flowers compared to other combination.

Table 7. Interaction effect of variety and growth media on number of flower

Treatments	**Number of flowers plant^{-1}**
V_1M_1	43.16 f
V_1M_2	51.42 d
V_1M_3	46.06 e
V_2M_1	60.13 c
V_2M_2	67.03 a
V_2M_3	63.10 b
SE (±)	0.36
CV (%)	0.81

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

4.9 Number of fruits plant^{-1}

Variety had a significant influenced on number of fruits plant^{-1} of tomato in aquaculture system (Figure 8 and Appendix VII). The variety V_2 produced the maximum number of fruits plant^{-1} over others treatment. The value of this trait for V_2 variety was 33.11 while the values for V_1 variety was 23.67. This might be due to the genetic variation among varieties where maximum nutrient uptake by V_2 from aquavegeculture system. Because nutrient update and vegetative growth as well as reproductive development depend on the candidate gene of tomato (Xia *et al*. 2012).

Number of fruits plant^{-1} showed significant variation for the different growth media in aquaculture system (Figure 8 and Appendix VII). The media M_2 produced the maximum number of fruits plant^{-1} (31.01) while treatment M_1 seeds produced the minimum number of fruits plant^{-1} of tomato. Probably, media M_2 facilitated proper aeration and helped plant to uptake of nutrient from aquavegeculture system for proper growth of plant. The aquavegeculture system also provided adequate nutrient for reproductive development of plant. Salam *et al.* (2014), Philippe (2010), Steve and Rinehart (2010), Endut *et al*. (2009), Hu *et al*. (2008), Nelson (2008), Li *et al.* (2007), Diver (2006), Fitzsimmons (2006), Rakocy *et al*. (2006) also reported the similar finding.

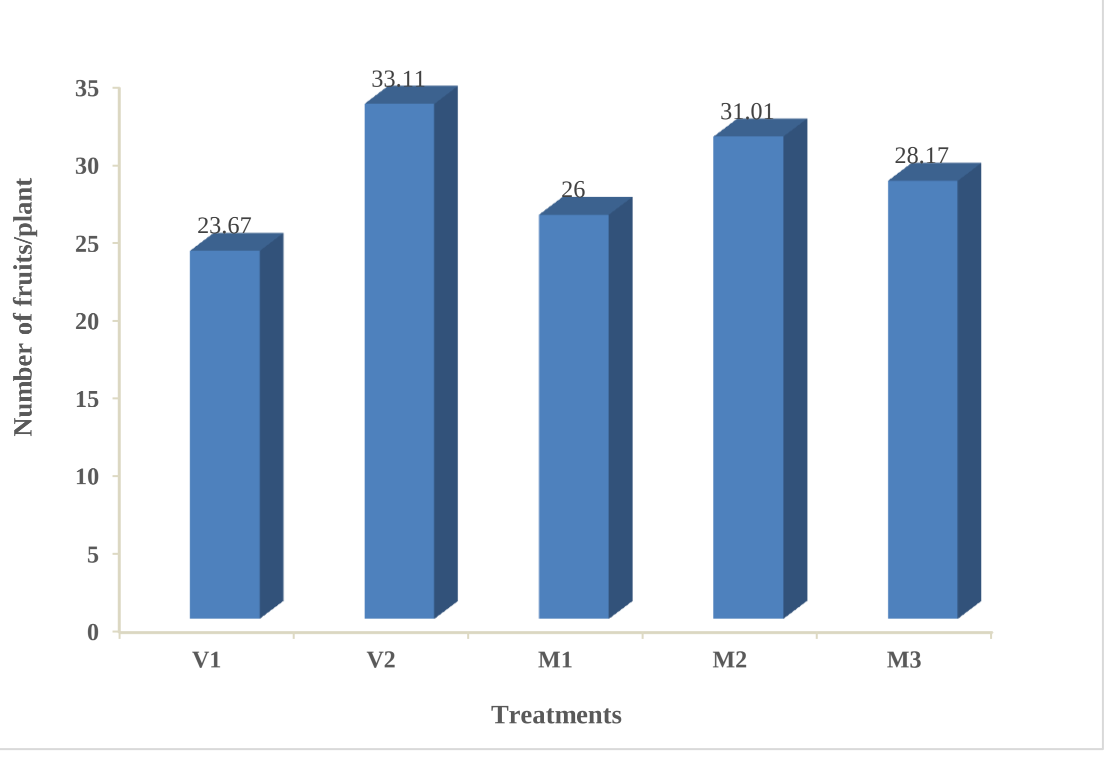

Figure 8. Effect of variety and growth media on number of fruits plant^{-1}

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

The interaction effect variety and growth media had produced the positively significant number fruits plant^{-1} (Table 8 and Appendix VII). The number of fruits plant^{-1} ranges from 21.11 to 36.02. The highest value of fruits plant^{-1} (36.02) was recorded in V_2M_2 while the lowest value of this trait was found in V_1M_1 (21.11).

Table 8. Interaction effect of variety and growth media on number of fruits

Treatments	Number of fruits plant^{-1}
V_1M_1	21.11
V_1M_2	26.12
V_1M_3	24.02
V_2M_1	31.09
V_2M_2	36.02
V_2M_3	32.33
SE (±)	0.46
CV (%)	2.0

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

4.10 Fruit weight

The fruit weight of tomato had a significant influenced due to the variety. It was noticed that variety V_2 produced the highest value of fruit weight over the variety V_1 (Figure 9 and Appendix VIII). The values of fruit of the variety V_2 was 66.01 g and the value of the same trait for V_1 was 46.48 g. This might be due to the genetic variation among varieties where maximum nutrient uptake by V_2 from aquavegeculture system. Because nutrient update and vegetative growth as well as reproductive development depend on the candidate gene of tomato (Xia *et al.* 2012).

The fruit weight of tomato showed significant variations with the different levels growth media in aquaculture system. Data revealed that the growth media M_2 produced the highest fruit weight over the other treatments (Figure 9 and

Appendix VIII). The media M_2 produced the highest value of fruit weight (61.72 g) and the lowest value of fruit weight was obtained from M_1 treatment (51.03 g). This might be due to that, media M_2 facilitated proper aeration and bacteria in the media made nutrient available for plant which was provided from fish water during irrigation and helped plant to uptake nutrient from aquavegeculture system for proper growth of plant. The aquavegeculture system also provided adequate nutrient for reproductive development of plant. Salam *et al.* (2014), Dunn (2012), Jessica (2012), Li *et al.* (2007), Tyson *et al.* (2007), Rakocy *et al.* (2006), Diver (2006), Fitzsimmons (2006), Rakocy *et al.* (2006), Saleh (2006) also reported the similar finding.

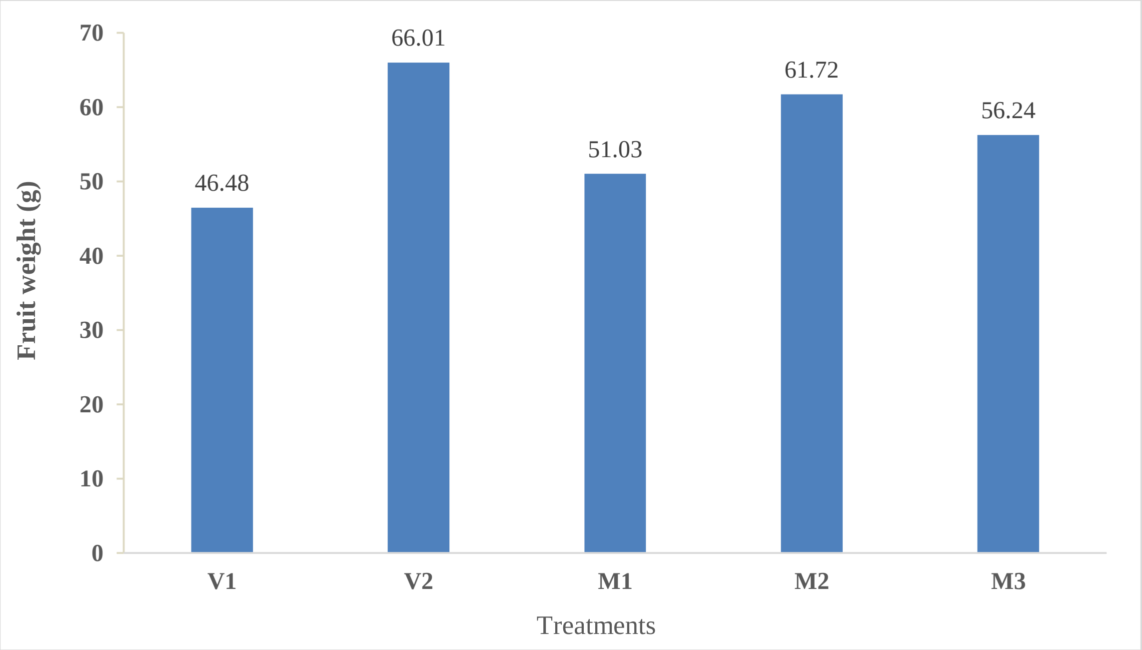

Figure 9. Effect of variety and growth media on fruit weight

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

The interaction effect of variety and growth media showed significant effect on fruit weight of tomato. The fruit weight ranges from 41.03 g to 71.11 g (Table 9 Appendix VIII). The interaction V_2M_2 produced the highest fruit weight (71.11 g) while the lowest fruit weight (41.03 g) was produced by V_1M_1 combination compared to others.

Table 9. Interaction effect of variety and growth media on fruit weight, fruit length and fruit diameter

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)
V_1M_1	41.03	3.10	3.30 d
V_1M_2	52.44	3.30	3.80 b
V_1M_3	46.13	3.16	3.57 bc
V_2M_1	61.02	4.16	3.50 cd
V_2M_2	71.11	5.46	4.93 a
V_2M_3	66.22	5.30	3.80 b
SE (±)	0.32	0.09	0.07
CV (%)	0.71	2.86	2.36

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

4.11 Fruit length

Due to the different variety the fruit length showed positively significant differences (Figure 10 and Appendix VIII). The fruit length ranges from 3.92 cm to 4.24 cm. The highest value of fruit length was recorded in V_2 treatment and the lowest values of fruit length was recorded in V_1 treatment. This might be due to the genetic variation among varieties where maximum nutrient uptake by V_2 from aquavegeculture system. Because nutrient update and vegetative growth as well as reproductive development depend on the candidate gene of tomato (Xia *et al*. 2012).

The fruit length showed statistically significant impact due to different types of growth media of tomato cultivation in aquaculture system (Figure 10 and Appendix VIII). The highest value of fruit length was recorded in M_2 while the lowest value of fruit length was in M_1. The fruit length ranges from 3.13 cm to 5.33 cm. Probably, media M_2 facilitated proper aeration and helped plant to uptake of nutrient from aquavegeculture system for proper growth of plant. The aquavegeculture system also provided adequate nutrient for reproductive development of plant. Michael (2012), Dunn (2012), Rana *et al*. (2011), Normala *et al*. (2010), Philippe (2010), Steve and Rinehart (2010), Endut *et al*. (2009), Graber *et al*. (2008), Hu *et al*. (2008), Nelson (2008), Diver (2006), Fitzsimmons (2006), Rakocy *et al*. (2006) also reported the similar finding.

Combine effect of variety and growth media produced statistically significant fruit length of tomato (Table 9 and Appendix VIII). For the combine effect the value of fruit length ranges from 3.10 cm to 5.46 cm. The highest value of fruit length was found in V_2M_2 and the lowest value of fruit length was found in V_1M_1 combination compared to the others interaction.

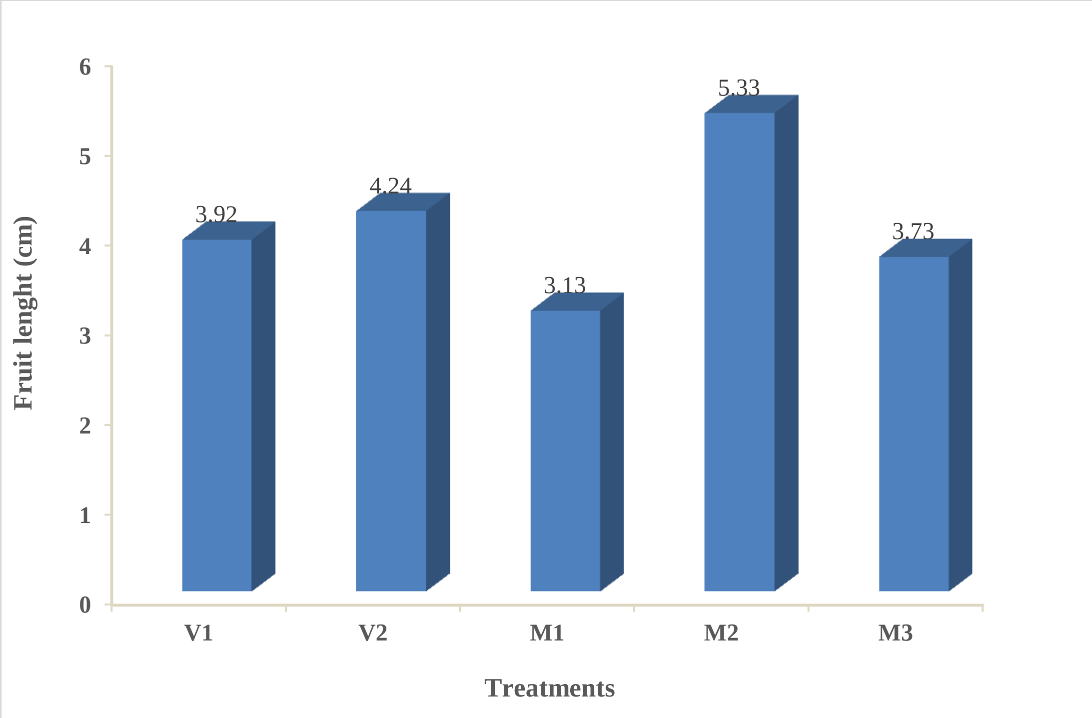

Figure 10. Effect of variety and growth media on fruit length

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

4.12 Fruit diameter

The fruit diameter showed positively significant difference at different types of variety for tomato cultivation in aquaculture system (Figure 11 and Appendix VIII). Due to different levels of variety, the range of fruit diameter was found 3.55 cm to 4.07 cm. The highest value of fruit diameter was recorded in the variety V_2 while the lowest fruit diameter was recorded in V_1. The fact that the genetic variation among varieties where maximum nutrient uptake by V_2 from aquavegeculture system. Because nutrient update and vegetative growth as well as reproductive development depend on the candidate gene of tomato (Xia *et al*. 2012).

Impact of different growth media on tomato showed positively significant effect for fruit diameter of tomato (Figure 11 and Appendix VIII). The highest value of fruit diameter was found in M_2 while the lowest value of fruit diameter was recorded in M_1 treatment. The value of fruit diameter ranges from 3.40 cm to 4.36 cm. This might be due to that, media M_2 facilitated proper aeration and helped plant to uptake of nutrient from aquavegeculture system for proper growth of plant. The aquavegeculture system also provided adequate nutrient for reproductive development of plant. Salam *et al.* (2014), Dunn (2012), Jessica (2012), Bernstein (2011), Rakocy (2011), Rana *et al*. (2011), Normala *et al*. (2010), Endut *et al*. (2009), Graber *et al*. (2008), Hu *et al*. (2008), Nelson (2008), Li *et al.* (2007), Rakocy *et al.* (2006), Diver (2006), Fitzsimmons (2006) also reported the similar finding.

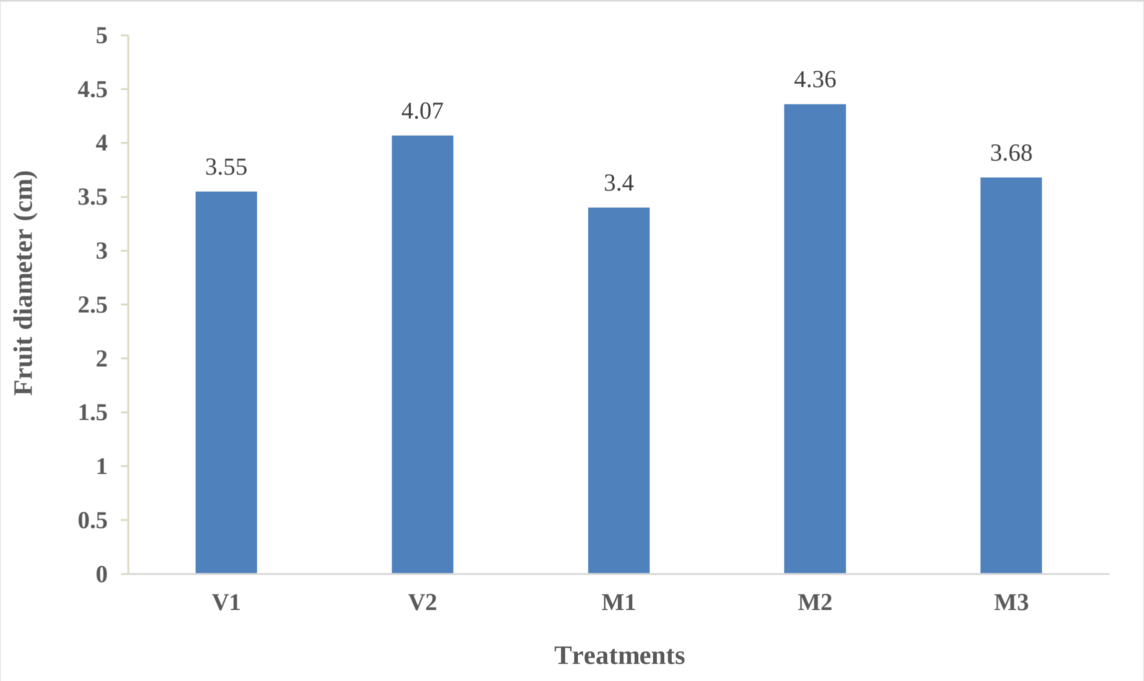

Figure 11. Effect of variety and growth media on fruit diameter

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

Combine effect of variety and growth media showed positively significant impact on fruit diameter of tomato in aquaculture system (Table 9 and Appendix VIII). The fruit diameter ranges from 3.30 cm to 4.93 cm while V_2M_2 produced the highest fruit diameter and V_1M_1 produced the lowest fruit diameter.

4.13 Yield plant^{-1}

The total yield plant^{-1} of tomato showed statistically significant variations with the different varietal treatment. From the experiment it was observed that the variety V_2 produced the highest yield plant^{-1} than to variety V_1 (Figure 12 and Appendix VIII). The yield plant^{-1} for variety V_2 was 840.11 g and for variety V_1 was 606.67 g. Probably the genetic variation among varieties where maximum nutrient uptake by V_2 from aquavegeculture system. Because nutrient update and vegetative growth as well as reproductive development depend on the candidate gene of tomato (Xia *et al*. 2012).

The yield plant^{-1} showed significant variations due to different types of growth media. The data revealed that M_2 produced the highest yield plant^{-1} (858.67 g) and M_1 produced the lowest values of yield plant^{-1} (606.67 g) compared to others media (Figure 12 and Appendix VIII). The fact that, media M_2 facilitated proper aeration and helped in growth and multiplication of bacteria which made plant nutrient available and helped plant to uptake nutrient from aquavegeculture system for proper growth of plant. The aquavegeculture system also provided adequate nutrient for reproductive development of plant. Salam *et al.* (2014), Philippe (2010), Steve and Rinehart (2010), Endut *et al*. (2009), Andreas and Junge (2008), Graber *et al*. (2008), Nelson (2008), Li *et al.* (2007), Tyson *et al*. (2007), Diver (2006), Rakocy *et al*. (2006), Saleh (2006) also reported the similar finding.

The interaction effect variety and growth media (VM) had produced positively significant yield plant^{-1}. The highest values of yield plant^{-1} was recorded in V_2M_2 and the lowest value of yield plant^{-1} was found in V_1M_1 interaction (Table 10 Appendix VIII). The yield plant^{-1} ranges from 507.69 g to 1009.71 g.

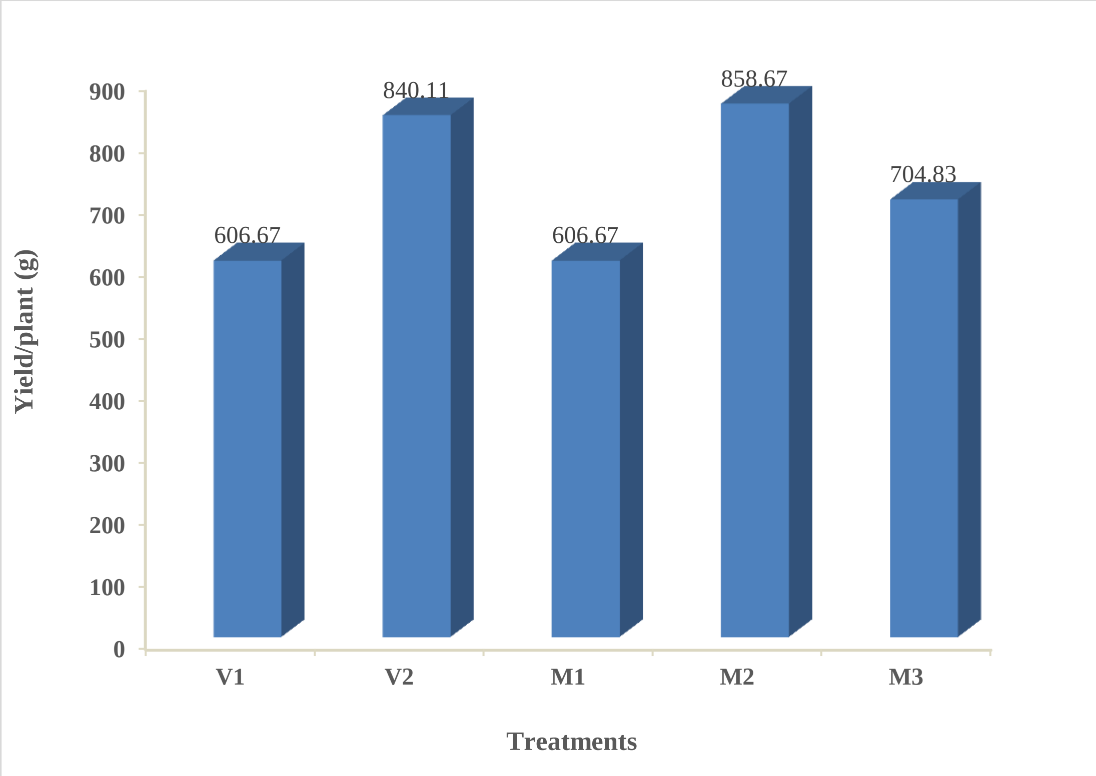

Figure 12. Effect of variety and growth media on yield plant^{-1}

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

Table 10. Interaction effect of variety and growth media on yield plant^{-1}

Treatments	Yield plant^{-1} (g)
V_1M_1	507.69 e
V_1M_2	707.74 c
V_1M_3	604.68 d
V_2M_1	705.70 c
V_2M_2	1009.71 a
V_2M_3	805.03 b
SE (±)	1.31
CV (%)	0.22

V_1: Exotic tomato line (AVRDC), V_2: BARI Tomato15; M_1= Broken stone, M_2: 50% khoa + 50% broken stone, M_3: Khoa; Means were separated by Tukey's test at $P \leq 0.05$.

4.14 Fish production

Data on different parameters i.e. length gain, weight gain and percent weight gain of fish was taken at different dates (Table 11). Table represented that the studied parameter showed increasing trend up to the final harvest of fish. Table also demonstrated that the survival rate of the harvest fish was 85.71% while the production per tank was 2.51 kg.

Table 11. Fish length, weight gain, survival rate and production in different sampling dates

Date	Length gain (cm)	Weight gain (g)	Percent weight gain	Survival rate (%)	Production (kg/Tank)
11.11.16	5.5±0.65	4.34±1.25	0	85.71	2.51
26.11.16	6.25±0.55	7.44±1.35	71.42±8.0		
10.12.16	7.92±0.48	12.25±1.22	64.65±9.62		
25.12.16	9.75±0.22	21.12±1.33	72.40.65±9.01		
10.01.17	10.80±0.57	40.01±1.05	89.44±21.05		
26.01.17	13.64±0.33	65.32±1.35	63.25±28.57		
09.02.17	17.45±0.11	78.22±0.33	19.75±12.55		
20.02.17	18.05±0.06	83.95±0.10	17.32±7.69		

CHAPTER V

SUMMARY AND CONCLUSION

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The present investigation indicated that the effect of different growing media on growth and yield of tomato varieties in roof top aquavegeculture system had a positive effect on vegetative and reproductive development as well as yield of tomato.

Plant height increased gradually with the advancement of growth stage and up to harvest. The tallest plant was obtained from the V_2 (44.22 cm, 73.22 cm and 81.00 cm at 30, 60 DAT and during harvest, respectively) over the variety V_1. Plant height showed significant variations for the different growth media. Data revealed that media M_2 produced the tallest plant (42.00 cm, 71.33 cm and 78.67 cm at 30, 60 DAT and during harvest, respectively) over the M_1 (34.50 cm, 58.50 cm and 69.17 cm at 30, 60 DAT and during harvest, respectively). The highest plant height was recorded from V_2M_2 interaction compared to others. Here the plant height ranges from 28.01 cm to 48.12 cm, 48.99 cm to 78.66 cm and 62.30 cm to 86.11 cm at 30, 60 DAT and during harvest, respectively.

The maximum number of leaves (12.84, 29.22 and 45.21) was obtained from the V_2 compared to the V_1 (8.33, 22.77 and 33.00) at 30, 60 DAT and during harvest, respectively. The data revealed that M_2 produced the maximum number of leaves (12.58, 28.67 and 43.06 at 30, 60 DAT and during harvest, respectively) and M_1 produced the minimum number of leaves (8.78, 23.83 and 35.11 at 30, 60 DAT and during harvest, respectively). The interaction V_2M_3 produced the maximum number of leaves (15.00, 32.00 and 49.23 at 30, 60 DAT and during harvest, respectively) while V_1M_1 produced the minimum number of leaves (6.40, 20.33 a d 29.01 at 30, 60 DAT and during harvest, respectively).

From the experiment it was observed that variety V_2 helped to produce maximum number of branches plant^{-1} of tomato (4.34) while the minimum number of branches were observed in variety V_1 (3.33). Mean number of branch showed a wide range of variations where highest number of branch plant^{-1} (4.88) was recorded from the media M_2 while M_1 produced lowest number of branches (2.76) compare to others media. The interaction V_2M_2 produced the maximum number of branches (5.36) while V_1M_1 produced the minimum number of branches (2.37) compared to other combination.

The variety V_2 produced highest foliage coverage at all sampling dates over the other variety. The highest foliage coverage was produced from the media M_2 and the lowest foliage coverage was observed from the M_1 treatment. The highest foliage coverage was given by V_2M_2 compared to others combination.

The variety V_2 produced the highest value of length of internode (5.03 cm) compared to V_1 (4.33 cm). The highest value of length of internode (5.14 cm) was produced by M_2 while the lowest value of this trait was produced by M_1 (4.20 cm). The ranges of length of internode was 5.42 cm. The interaction V_2M_2 produced the highest value of length of internode (5.42 cm).

From the data it was observed that variety V_2 helped to produce maximum chlorophyll content of tomato plant (55.00) while the minimum chlorophyll content was observed in variety V_1 (45.33). The highest chlorophyll content (54.23) was recorded from the media M_2 while media M_1 produced the lowest value (47.03) compared to other media. The interaction V_2M_2 produced the maximum chlorophyll content (59.00) while V_1M_1 produced the lowest chlorophyll content (42.03) compared to other combination.

In the varietal treatment, 20.56 nos cluster plant the was produced by V_2 treatment while 15.78 nos cluster plant the was produced by V_1 treatment. The treatment M_2 produced the maximum number of cluster plant^{-1} and minimum number of cluster was recorded from M_1 treatment. The cluster number of M_2 treatment was 20.50 and the cluster number of M_1 treatment was 16.16. The cluster number ranges from 14.04 to 23.16. The maximum number of cluster plant^{-1} was recorded from V_2M_2 combination (23.16 nos) while the minimum number of cluster plant^{-1} was found in V_1M_1 combination (14.04 nos) compared to others.

The variety V_2 produced the maximum number of flowers (63.42) compared to the variety V_1 (46.88). It was noticed that the maximum number of flowers plant^{-1} obtained from M_2 and the minimum number of flowers was observed from M_1 treatment. In the present study, data showed that V_2M_2 produced the maximum number of flowers compared to other combination.

The variety V_2 produced the maximum number of fruits plant^{-1} over others treatment. The value of this trait for V_2 variety was 33.11 while the values for V_1 variety was 23.67. The media M_2 produced the maximum number of fruits plant^{-1} (31.01) while treatment M_1 seeds produced the minimum number of fruits plant^{-1} of tomato. The number of fruits plant^{-1} ranges from 21.11 to 36.02. The highest value of fruits plant^{-1} (36.02) was recorded in V_2M_2 while the lowest value of this trait was found in V_1M_1 (21.11).

The values of fruit of the variety V_2 was 66.01 g and the value of the same trait for V_1 was 46.48 g. The media M_2 produced the highest value of fruit weight (61.72 g) and the lowest value of fruit weight was obtained from M_1 treatment (51.03 g). The interaction V_2M_2 produced the highest fruit weight (71.11 g) while the lowest fruit weight (41.03 g) was produced by V_1M_1 combination compared to others.

The fruit length ranges from 3.92 cm to 4.24 cm. The highest value of fruit length was recorded in V_2 treatment and the lowest values of fruit length was recorded in V_1 treatment. The highest value of fruit length was recorded in M_2 while the lowest value of fruit length was in M_1. The fruit length ranges from 3.13 cm to 5.33 cm. For the combine effect the value of fruit length ranges from 3.10 cm to 5.46 cm. The highest value of fruit length was found in V_2M_2 and the lowest value of fruit length was found in V_1M_1 combination compared to the others interaction.

Due to different levels of variety, the range of fruit diameter was found 3.55 cm to 4.07 cm. The highest value of fruit diameter was recorded in the variety V_2 while the lowest fruit diameter was recorded in V_1. The highest value of fruit diameter was found in M_2 while the lowest value of fruit diameter was recorded in M_1 treatment. The value of fruit diameter ranges from 3.40 cm to 4.36 cm. The fruit diameter ranges from 3.30 cm to 4.93 cm while V_2M_2 produced the highest fruit diameter and V_1M_1 produced the lowest fruit diameter.

Conclusion

From the experiment it was observed that the variety V_2 produced the highest yield plant^{-1} than to variety V_1. The yield plant^{-1} for variety V_2 was 840.11 g and for variety V_1 was 606.67 g. The data revealed that M_2 produced the highest yield plant^{-1} (858.67 g) and M_1 produced the lowest values of yield plant^{-1} (606.67 g) compared to others media. The highest values of yield plant^{-1} was recorded in V_2M_2 and the lowest value of yield plant^{-1} was found in V_1M_1 interaction. The yield plant^{-1} ranges from 507.69 g to 1009.71 g. Therefore, it can be concluded that the variety V_2 and media M_2 had a positive impact on vegetative growth and yield of tomato.

Recommendation

The present study suggests to use the mixture of 50% khoa and 50% broken stone as a media for aquavegeculture system. The study also suggests to include BARI tomato15 as crop in this system. But it is not conclusive because of the limitation of the present study as it did not include more media and more tomato varieties. Therefore, further study with more media and more tomato varieties may provide more conclusive and precise recommendation.

REFERENCES

REFERENCES

Ahmed, N. and Garnett, S. T. 2011. Integrated rice-fish farming in Bangladesh: meeting the challenges of food security. *Food Sec*., **3**: 81-92.

Al-Hafedh, Y. S., Alam, A. and Beltagi, M. S. 2008. Food production and water conservation in a recirculating aquaponics system in Saudi Arabia at different ratios of fish feed to plants. *J. World Aquaculture Soc*., **39**(4): 510-520.

Andreas, G. and Junge, R. 2008. Aquaponics Systems: Nutrient recycling from fish waste water by vegetable production. Zurich University of Applied Sciences, Institute for Natural Resource Sciences Gruental, CH-8820 Waedenswil, Switzerland. *Desalination*, **246**: 102-107.

Anonymous. 2009. Annual Weather Report, IPSA. Meteorological Station, IPSA, Salna, Gazipur. p. 8-15.

Bernstein, S. 2011. Aquaponic Gardening: A step-by-step guide to raising vegetables and fish together. Gabriola Island, Canada: New Society Publishers. Science Education International.

Britto, D. T., Herbert, J. and Konzucker, D. 2002. NH_4+ toxicity in higher plants: a critical review. *J. Plant Physiol.*, **159**: 567-584.

Brahic, C. 2007. Cooling percentages by Green roofs. New Scientist. Retrieved March 12, 2018.

Chand, S., Anwar, M. and Patrs, D. D. 2006. Influence of long term application of organic and inorganic fertilizer to build up soil fertility and nutrient uptake in mint-mustard cropping sequence. *Commun. Soil Sci. Anal.*, **37**:63-76.

Diver, S. 2006. Aquaponics- Integration of hydroponics with aquaculture. ATTRA-National Sustainable Agriculture Information Service. Available from: http//attm.ncat.org/attm-pub/PDF/aquaponics.pdf.

DoF. 2012. Fishery Statistical Yearbook of Bangladesh, Fisheries Recourses Survey System, Department of Fisheries, Dhaka, Bangladesh. pp. 3-41.

Dunn, P. 2012. An aquaponics experiment where tilapia and tomatoes can be best buddies. Newspaper Source: Times-News, The (Twin Falls, ID) 12 Dec. 2012 Plus. Web 24 Jan, 2013.

Endut, A., Jusoh A., Ali N., Nik, W.W.N.S. and Hassan, A. 2009. Effect of flow rate on water quality parameters and plant growth of water spinach *(Ipomoea aquatica)* in an aquaponic re-circulating system. *J. Desalin. Water Treat.* **5**: 19-28.

Estim, A. and Mustafa, S. 2010. Aquavegecultures application in a marine hatchery system. *Aquavegeculture J.*, **57**:26-34.

FAO. 2012. Food and Agricultural Organization of the United Nations, the State of World Fisheries and Aquaculture.

Fitzsimmons, H. 2006. Tilapia production systems in the city: technical advances, trends and challenges. *Rev. Fish Sci.*, **10**(3-4): 465–498.

Ghaly, A. E., Kamal, M. and Mahmoud, N. S. 2004. Phytoremediation of aquaculture wastewater for water recycling and production of fish feed. *Aquaponics J*., **3**(6): 11-13.

Graber, *et al*. 2008. Aquaponics Systems: Nutrient recycling from fish wastewater by vegetable production. *Desalination*, **246**: 147-156.

Hu, M. H., Ao, Y. S., Yang, X. E. and Li, T. Q. 2008. Treating eutrophic water for nutrient reduction using an aquatic macrophyte (*Ipomoea aquatica* Forsskal) in a deep flow technique system. *J. Agric. Water Manage.*, **95**: 607-615.

Ingrid, P. 2013. Effect of fish extract on growth and yield of crops. *Ca. Univ. J. Biol. Sci.*, **5**(1): 55-62.

Jason, D. 2009. Vegetable production in aquaculture system. *J. Food Agric.*, **12**(3): 89-95.

Jason, D. and Austin, M. A. 2013. Hydroponic is the best option for fish and vegetable production. *Egyptian J. Hortic*., **8**(5): 120-126.

Jessica, M. L. S. 2012. Effect of fish extract on vegetative growth, flowering and yield of sponge gourd. *Plant Sci. Res. J*., **5**(1-2): 95-98.

Kamal, S. M. 2006. Aquaponic production of nile tilapia (*Oreochromis niloticus*) and Bell pepper (*Capsicum annuum*) in recirculating water system. *Egypt. J. Aqual. Biol. Fish*, **10**: 85-97.

Li, M., Wu, Y. J., Yu, Z. L., Sheng, G. P. and Yu, H. Q. 2007. Nitrogen removal from eutrophic water by floating-bed-grown water spinach (*Ipomoea aquatica* Forsk.) with ion implementation. *J. Water Res.,* **41**: 3152-3158.

Lin, Y. F., Jing, S. R., Lee, D. Y. and Wang, T. W. 2005. Nutrient removal from aquaculture wastewater using a constructed wetlands system. *J. Aquaculture Sci*. Pub., **5**(6): 12-16.

Liu, K. 2018. Energy efficiency and environmental benefits of rooftop gardens (PDF). National Research Council Canada. Retrieved March 12, 2018.

Masser, M. P., Rakocy, J. E. and Losordo, T. M. 1992. Recirculating aquaculture tank production systems: Management of recirculating systems (No. 452). Retrieved from http://aqua.ucdavis.edu/DatabaseRoot/pdf/452RFS.PDF.

Michael, A. A. 2012. Aquaculture in roof is for homestead gardening. *J. Hortic*. *Food Agric*., **26** (7): 229-236.

Mustafa, S., Wahap, N. Abentin, E. and Annita, Y. S. K. 2010. Producing organic fish and mint in an aquavegeculture system: A model of green technology in action. *Aquavegeculture J.*, **58**:28-33.

Nelson, T. S. P. 2008. Effect of poultry manure on growth, yield and quality of some selected vegetables. *J. Agric*. *Seed Res*., **26**(1): 97-100.

Normala, W., Estim, A. and Kian, A. Y. S. 2010. Producing organic fish and mint in an aquaponics system. A Model of Green Technology in Action, Borneo Marine Research Institute, Sabah, Malaysia. *J. Aquaponics*, **58**(5):223-230.

Ong, B. 2003. Green plot ratio: an ecological measure for architecture and urban planning. *Landscape and Urban Planning*, 63 (4). Retrieved January 19, 2017, from Science Direct database.

Philippe, P. R. 2010. Fish and plant production in roof an economic viable technique. *Plant Archive*, **14**(1): 263-266.

Popma, T. and Masser, M. 1999. Tilapia life history and biology. Southern Regional Aquaculture Center. Publication No. 283.

Prinsloo, I. S., Titen, T. S. and Ramesh. S. R. 1999. Aquaculture with horticultural crops. *Adv. Plant Sci*., **20**(5): 30-38.

Racoky, J. E. and Hargreaves, J. A. 1993. Integration of vegetable hydroponics with fish culture: for Modern Aquaculture Proceedings Aquaculture Engineering Conference.American Society for Agril. Engineers, St. Joseph, MI.

Racoky, J. E., Donald, S. B., Shultz, R. C. and Thoman, E. S. 2004. Update on Tilapia and vegetable production in the USA Aquavegeculture system. In: New Dimension on Farmed Tilapia: Proceedings of the sixth Intl. Symposium on Tilapia in aquaculture, Manila, Philipines. p.676-690.

Rakocy, J. E., Masser, M. P. and Losordo, T. M. 2006. Recirculating aquaculture tank production systems. Aquaponics-Integrating Fish and Plant Culture, Department of Agriculture, USA. Publication No. 454. Pp.1-16.

Rakocy, J. E., Shultz, R. C., Bailey, D. S. and Thoman, E. S. 2004. Aquaponic production of tilapia and basil comparing a batch and staggered cropping system. *Acta Hortic*., **648**: 63-69.

Rakocy, J. E., Shultz, R. C., Bailey, D. S. and Thoman, E. S. 2011. Aquaponic production of tilapia and basil comparing a batch and staggered cropping system. *Acta Hortic*., **64**: 63-69.

Rana, S, Bag, S. K., Golder, D., Mukherjee, S., Pradhan, C. and Jana, B. B. 2011. Reclamation of municipal domestic wastewater by aquaponics of tomato plants. *Ecol. Eng*., **37**: 981–988.

Roe, B. R. and Midmore, D. J. 2008. Sustainable Aquaponics. Center for Plant and Water Science. CQ University, Rockhampton, Queensland, Australia. p. 78.

Roosta, H. R. and Hamidpour, M. 2013. Mineral nutrient content of tomato plants in aquaponic and hydroponic systems: Effect of foliar application of some macro-and micro-nutrients. *J. Plant Nutr*., **36**(13): 2070-2083.

Salam, M. A., Asadujjaman, M. and Rahman, M. S. 2013. Aquaponics for improving high density fish pond water quality through raft and rack vegetable production. *World J. Fish Mar. Sci*., **5**: 251-256.

Salam, M. A., Hashem, S. Asadujjaman, M. and Li. F. 2014. Nutrient recovery from in fish farming wastewater: an aquaponics system for plant and fish integration. *World J. Fish Mar. Sci*., **6**: 355-360.

Saleh, M. K. 2006. Aquaponic production of nile tilapia (*Oreochromis niloticus*) and bell pepper (*Capsicum annuum* L) in recirculating water system. *Egyptian J. Aquatic Biol. Fisheries*, **10**:85-97.

Savidov, M. 2004. A study on the effect of fish extract on yield, biochemical and physiological characters of tomato. International Conference on Agricultural & Horticultural Sciences. Hyderabad International Convention Centre, India.

Savidov, M. 2005. Effect of GABA application on the growth and yield of tomato in aquaponic system. *J. Agric. Technol. Biol*., **22** (5): 150-160.

Steve, D. and Rinehart, L. 2010. Aquaponics- Integration of Hydroponics with Aquaculture. *NCAT Agric. Spec*., **3**(6):28-32.

Timmons, M. B. 1996. Successes and failures in commercial recirculating aquaculture. Aquaculture Engineering Society Proceedings II. Natural

Resource, Agriculture, and Engineering Service (Cornell University; Ithaca, NY), pp. 141-150.

Timmons, M. B., Ebling, J. M., Wheaton, F. W., Summerfelt, S. T. and Vinci, B. J. 2002. Recirculating aquaculture systems(2nd Edition). Northern Regional Aquaculture Center Publication No. 01-002. Cayuga Aqua VenturesIthaca, New York.

Tyson, R. V., Simonne, E. H., Davis, M., Lamb, E. M., White, J. M. and Treadwell, D. D. 2007. Effect of nutrient solution, nitrate-nitrogen concentration, and pH on nitrification rate in perlite medium. *J. Plant Nutri.*, **30**: 901-913.

Villaverde, S., Garcia-Encina, P. A. and Fdz-Polanco, F. 1997. Influence of pH over nitrifying biofilm activity in submerged biofilters. *Water Resource*., **31**: 1180-1186.

Watanabe, W. O., Losordo, T. M., Fitzsimmons, K. and Hanley, F. 2002. Tilapia production systems in the americas: technical advances, trends and challenges. *Reviews Fisheries Sci*., **10**(3-4): 465–498.

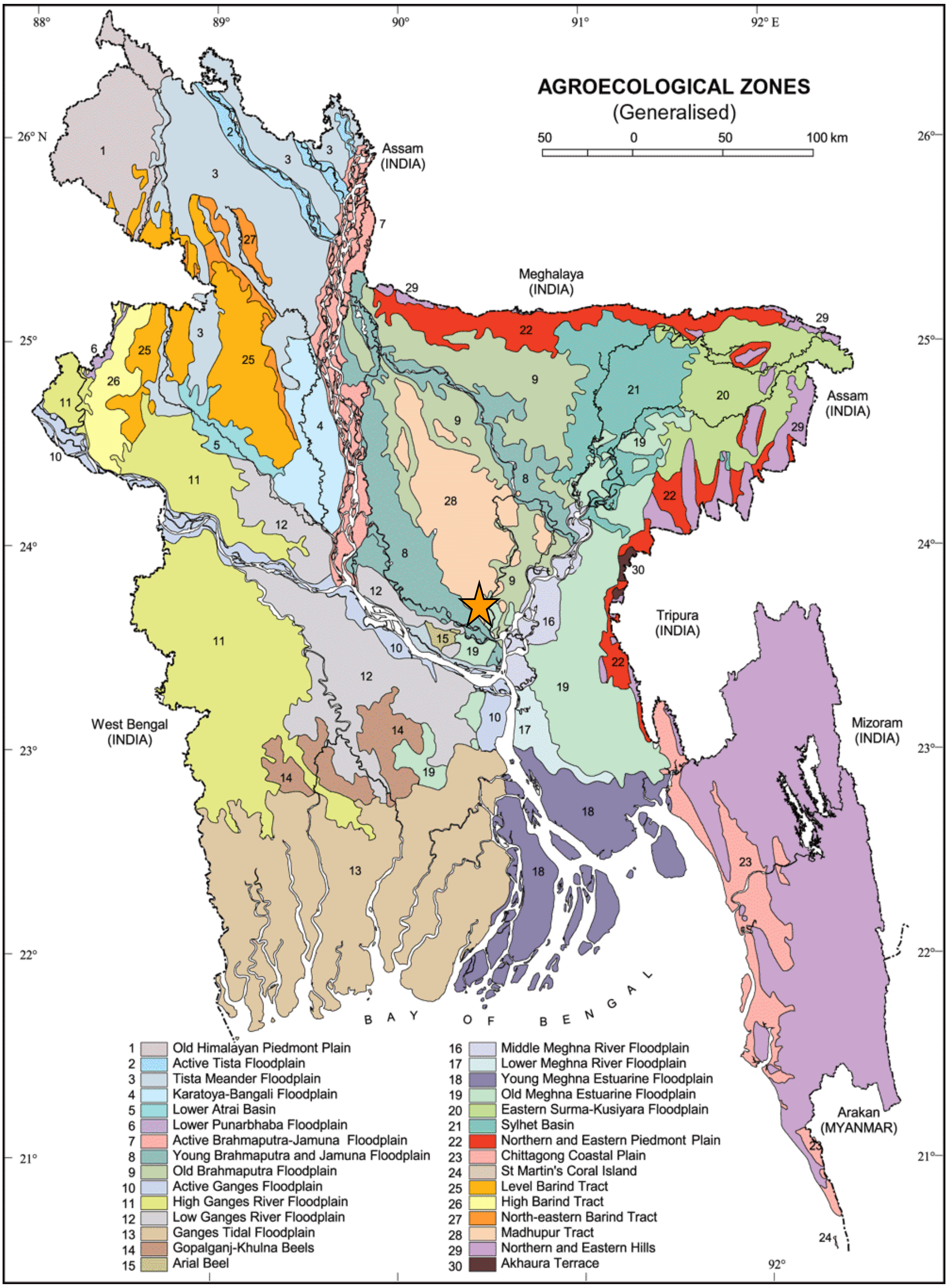
Wilson, A. 2004. Aquaponics Research RMIT University, Melbourne Australia. *Aquaponics J*., **5**(8):30-35.

Wilson, A. and Brian, V. L. 2006. A comparison of three different hydroponic sub-systems (gravel bed, floating and nutrient film technique) in an Aquaponic test system. *Aquaculture Intl*., **14**: 539–550.

Xia, X., Luo, Y., Yang, Y., Vinyard, B., Schneider, K. and Meng, J. 2012. Effects of tomato variety, temperature differential, and post–stem removal time on internalization of Salmonella enterica serovar Thompson in tomatoes. *J. Food Protection*, **75**(2): 297-303.

APPENDIX

Appendix I. Map showing the experimental sites under study



★ **The experimental site under study**

Appendix II. Monthly recorded the average air temperature, rainfall, relative humidity and sunshine of the experimental site during the period from December 2016 to May 2017.

Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall(mm)	Sunshine (hr)
	Maximum	Minimum			
December, 2016	26.4	14.1	69	12.8	5.5
January, 2017	25.4	12.7	68	7.7	5.6
February, 2017	28.1	15.5	68	28.9	5.5
March, 2017	32.5	20.4	64	65.8	5.2
April, 2017	38.9	23.6	70	76.4	5.7
May, 2017	40.5	24.5	75	80.6	5.8

Source: Sher-e-Bangla Agricultural University Weather Station

Appendix III. Factorial anova for plant height

Sources of variations	Degrees of Freedom	Mean square		
		Plant height (cm) at		
		30 DAS	60 DAS	Harvest
Replication	2	3.722	3.72	9.500
Variety (A)	1	709.389**	1283.56**	924.500**
Media (B)	2	86.056**	247.39**	135.500**
A×B	2	0.389	7.06*	0.500
Error	10	0.322	0.32	0.300

** means significant at 1% & * means significant at 5%.

Appendix IV. Factorial anova for number of leaves

Sources of variations	Degrees of Freedom	Mean square		
		Number of leaves at		
		30 DAS	60 DAS	Harvest
Replication	2	0.9584	0.500	3.50000
Variety (A)	1	91.1700**	186.889**	648.000**
Media (B)	2	21.8220**	36.167**	96.0000**
A×B	2	0.4080	0.722	$2.840E^{-29}$
Error	10	0.1408	0.433	0.50000

** means significant at 1% & * means significant at 5%.

Appendix V. Factorial anova for number of branches

Sources of variations	Degrees of Freedom	Mean square		
		Number of branches	Foliar coverage (cm^2)	Length of internode (cm)
Replication	2	0.52667	10.72	0.05901
Variety (A)	1	4.50000**	1476.06**	2.20500**
Media (B)	2	6.72167**	207.72**	1.35017**
A×B	2	0.07167*	2.06*	0.10452*
Error	10	0.01000	0.32	0.00001

** means significant at 1% & * means significant at 5%.

Appendix VI. Factorial anova for SPAD value

Sources of variations	Degrees of Freedom	Mean square
		SPAD value
Replication	2	5.167
Variety (A)	1	420.500**
Media (B)	2	75.500**
A×B	2	0.500
Error	10	0.167

** means significant at 1% & * means significant at 5%.

Appendix VII. Factorial anova for no. of cluster, no. of flower and no. of fruits

Sources of variations	Degrees of Freedom	Mean square		
		No. of cluster	No. of flower	No. of fruits
Replication	2	2.000	8.74	3.722
Variety (A)	1	102.722**	1230.74**	401.389**
Media (B)	2	28.667**	87.57**	37.722**
A×B	2	0.222	0.96*	1.389*
Error	10	0.400	0.20	0.322

** means significant at 1% & * means significant at 5%.

Appendix VIII. Factorial anova for no. of cluster, no. of flower and no. of fruits

Sources of variations	Degrees of Freedom	Mean square			
		Fruit weight (g)	Fruit length (cm)	Fruit diameter (cm)	Yield plant^{-1} (g)
Replication	2	8.08	0.30167	0.00667	196
Variety (A)	1	1714.64**	0.46722**	1.22722**	245233**
Media (B)	2	172.64**	8.14500**	1.481678**	96805**
A×B	2	1.04*	0.35389*	0.42056*	5289*
Error	10	0.16	0.01367	0.00800	3

** means significant at 1% & * means significant at 5%.