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# Impact of calcium supplement through egg shell on tomato (*Solanum lycopersicum*) production in aquaponic system

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## Abstract
The present study was carried out for 109 days from 6th November, 2016 to 23rd February, 2017 to assess how tomato and fish production respond to calcium supplement in aquaponics. Tilapia (*Oreochromis niloticus*) was released at the rate of 10 fish/16 L water tank and two tomato saplings were planted in each replication. As the source of calcium, chicken egg shell powder was added in $T_1$ (1kg/decimal) and $T_2$ (1.5kg/decimal) and $T_3$ was control. The daily growth rate and survival rate were 1.68±0.009, 1.59±0.016, 1.6±0.03% and 66, 70, 60% in treatment $T_1$, $T_2$ and $T_3$, respectively. The higher production of tomato (73.58 tons/ha/109 days) and fish (295.03 tons/ha/109 days) $T_1$ signifies the potential of egg shell powder as source of calcium in addressing disease problem in tomato.

**Keywords** Aquaponic, calcium, egg shell, blossom end rot, tomato

## Introduction
Land gets shrinking, uncontrolled population growth and complex and unpredictable weather creates new challenges to the country's agriculture that highlighted developing new crop production system like aquaponic [1]. Aquaponics is a symbiotic relationship between aquaculture and hydroponics, where fish and plants grow harmoniously [2]. In aquaponic system tomato and tilapia are cultured widely. In case of tomato production in this integrated system some disorder is noticed in fruits. This called Blossom-end rot (BER) that occurs when cell wall calcium "concrete" is deficient during early fruit development. It causes significant crop loss in tomatoes, especially early in the season. Blossom-end rot (BER) is a physiological disorder which causes a dark, sunken area on the lower (blossom) end of tomato, pepper, and eggplant fruits [3]. Calcium, an essential macronutrient, plays an important role in the maintenance of plant physiology. Calcium is required in large amounts in the growing parts of plants. When rapidly growing fruit lack adequate calcium, tissue breakdown results [4]. About 95% of the dry eggshell is calcium carbonate [5] and so it is a good source of calcium. Present experiment was conducted to assess the effect of egg shell powder as calcium supplements on tomato production in the BAU aquaponic system and to compare fish and tomato production with and without calcium supplements.

## Materials and Methods
The experiment was carried out for 109 days 6th November, 2016 to 23rd February, 2017 at the roof of E-28 building of residential area, Bangladesh Agricultural University (BAU), Mymensingh. That place was selected for the experiment because the roof of the building was well protected and had good locked door system. It was a clean and dry place and also well exposed to the sunlight.

## Experimental Design
The experimental model comprises of 9 fish holding tanks (16 liter) and 9 food graded plastic containers (13.8×8.5 inch) for vegetable plants. Those are washed with detergent and sun dried. The vegetable containers were cut longitudinally and filled with 3 cm sized washed brick lets and sand.

One hole was made underneath of each container to make outlet for re-circulating water. In $T_1$ and $T_2$, 1 and 1.5 kg/decimal egg shell powder was added, respectively and $T_3$ was control (no egg shell powder). Egg shell powder was prepared using dumped egg shell which were collected from restaurant, washed and boiled for 20 minutes. Then sun dried and powdered using morter and pastle. Good quality tomato saplings of 10 days old were planted in two corners of each vegetable bed. The fish tanks were filled with 16 L tap water.

**Stocking of fish and feeding**

Tilapia fingerlings were bought and acclimatized and stocked in the tank at the density of 10 fingerlings/16 liter tank. A 12 watt submergible water pump was added in each tank to lift up waste water from fish tank to vegetable bed from 9:00 am to 5:00 pm. One aerator with one air stone was set in each tank to facilitate dissolve oxygen and prevent oxygen deficiency in the tank water. The fish was fed with commercial floating feed containing 30% protein twice (9.00 am and 4:00 pm) daily at the rate of 10%, 8% and 5% body weight per day in 1st, 2nd and 3rd month, respectively.

**Fish and vegetable sampling**

Fish and vegetable were sampled every 30 and 20 days interval, respectively. During each sampling, all fishes were caught from each replication with scoop net and individual length-weight was measured with an electronic compact balance (EK-600i) and wooden fish length measuring scale. The number of bunches, flowers and fruits were counted and plant height was measured at 20 days interval during the study period. The ripe tomato was weighed and recorded during harvesting.

**Fish and vegetable harvesting**

After 109 days the fish were harvested and their growth performance was measured such as length gain (cm), weight gain (g), percent weight gain, food conversion ratio (FCR), survival rate (%) and fish production (kg/ha). Ripen tomato was harvested and weighed up to the experiment completion. After the plants death the roots were picked up from the beds and washed carefully with tap water. Both the roots and plants were dried and weighed by electric balance.

**Physico-chemical parameters of fish tank water measurement**

Physico chemical parameters of tank water were measured to know the suitability of fish culture. Temperature (T) and pH were measured every 20 days interval with pH meters. Total nitrogen (N), Electric conductivity (EC), Carbonate ($CO_3$), Hydrogen carbonate ($HCO_3$), Potassium (K), Sulphur (S) and Sodium (Na) were measured two times interval during experiments. The tests were done in the Humboldt Soil Testing Laboratory, Soil Science department, Bangladesh Agricultural University.

**Data processing and analysis**

Fish and tomato production, plant growth, water quality and proximate composition was determined and expressed as mean ± (standard deviation). Data analyses performed using Microsoft Excel 2010, with an alpha set at 0.01 (significance at $p<0.01$). Mean values of fish production performances, plant growth rate, tomato yield, and proximate composition analyzed with one-way ANOVA. If there were significant differences at significant level of 0.01 then Duncan Multiple Range Test (DMRT) was used to compare the means to show significant differences between the treatments.

**Results and Discussions**

**Fish growth performance**

Tilapia was reared from 6th November, 2016 to 23rd February, 2017 for 109 days. The initial mean length of the fish was 5.11± 0.683 cm in all three treatments which increased to 15.36± 1.5, 14.18±0.97and 14.94±0.73cm in treatment $T_1$, $T_2$ and $T_3$ respectively and the mean initial weight was 2.7±0.99 g that increased to71.41±10.25, 57.94± 6.77 and 58.73±9.94g in treatment $T_1$, $T_2$ and $T_3$ respectively during harvesting time which is found lower than Salam *et al.* [6] recorded. There was no significant difference among fish length and weight in sampling dates (Fig. 1 and 2).That might be due to small experimental unit. The length and weight gain, percent length gain and survivality were lower and percent weight gain and Specific growth rate (%) were higher in the present experiment than the previous observation of Salam *et al.* [6]. The FCR for tilapia in the present experiment was bit higher 3.65, 3.819 and 4.84 in treatment $T_1$, $T_2$ and $T_3$ respectively than the findings of Rahmatullah *et al.* [7] and Quagrainie *et al.* [8] which were 2.69 and 3.1, respectively. The production of tilapia was 295.03, 235.81 and 202.83 tons/ha/109 days in treatment $T_1$, $T_2$ and $T_3$, respectively which were much more higher than the findings of Jahan [9] found 95.85 tons/ ha /116 days. It might be the cause of high stocking density. But there was no significant difference among the treatments (Table 1).

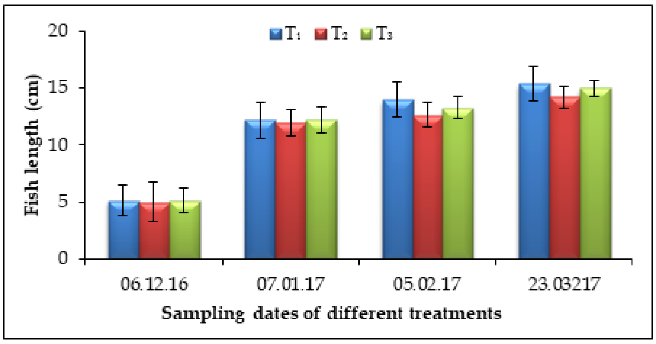


**Fig 1:** Length of fish at different treatments in different sampling dates. Vertical bar of each treatment represents standard deviations (±SD).

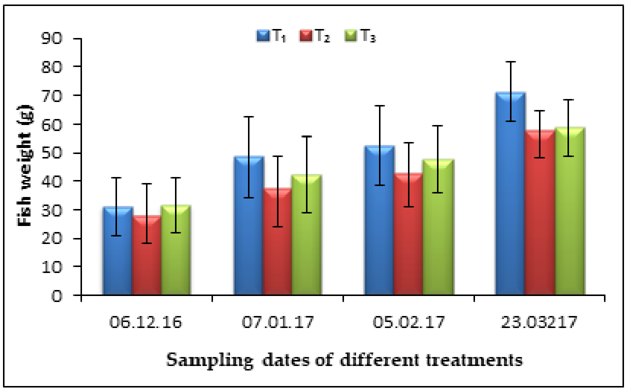


**Fig 2:** Weight of fish in different treatments in different sampling dates. Vertical bar of each treatment represents standard deviations (±SD).

**Table 1:** Growth performances of tilapia observed in different treatments during the study period

| Parameters | $T_1$ | $T_2$ | $T_3$ |
|---|---|---|---|
| Mean Initial Length (cm) | 5.11±0.683 | 5.01±0.74 | 5.11±0.72 |
| Mean Final Length (cm) | 15.36±1.5 | 14.18±0.97 | 14.94±0.73 |
| Mean Length Gain (cm) | 10.25±1.17 | 9.07±0.76 | 9.83±0.64 |
| Percent Length Gain (%) | 197.98±21.65 | 183.22±15.209 | 192.45±12.65 |
| Mean Initial Weight (g) | 2.7±0.99 | 2.37±0.77 | 2.37±0.77 |
| Mean Final Weight (g) | 71.41±10.25 | 57.94±6.77 | 58.73 ±9.94 |
| Mean Weight Gain (g) | 68.63±1.6 | 55.15±2.26 | 55.94±4.22 |
| Percent Weight Gain (%) | 2840.788±201.518 | 2325.32±94.89 | 2348.242±176.21 |
| Specific growth rate (%) | 1.68±0.0095 | 1.59±0.016 | 1.6±0.03 |
| Survival Rate (%) | 66% | 70% | 60% |
| Food conversion ratio (FCR) | 3.65 | 3.819 | 4.84 |
| Production (tons/ha/109 days) | 295.03 | 235.81 | 202.83 |

$T_1$=Treatment 1 (with 1 kg/decimal egg shell powder addition), $T_2$=Treatment 2 (with 1.5 kg/decimal egg shell powder addition) and $T_3$= control (no egg shell powder is added).

**Plant height and weight, root height and weight, no. of bunches, flowers, fruits and tomato production**

The highest mean height of the plant was found 81.83±17.29 cm in treatment $T_1$ on 23rd February 2017 in present experiment which was higher than the findings of Cole *et al.* [10] who use magnesium ammonium phosphate (MAP) as fertilizer. At the same time the plant height in treatment $T_2$ and $T_3$ was 54.58±19.72 and 53.75±21.57 cm, respectively (Fig.3). There was difference but no significant difference in plant heights among treatments. On the other hand, the highest mean weight of the plant was found164± 46.16 g in treatment $T_1$ at the final harvesting which was higher than the previous finding [9] and the highest root height and the weight were measured 36.33±5.68cm and 54.5±10.13 g, respectively in treatment $T_1$.Moreover, the highest flower, bunch and fruit number were measured 17.16±1.83, 5.3±1.03 and 27.0± 2.36, in treatment $T_3$, $T_1$ and $T_2$, respectively (Fig. 4 and Table 2). In previous experiment the highest fruit number of the plant was found 25 using magnesium ammonium phosphate (MAP) and 23 using controlled release fertilizer (CRF) [10].Total tomato productions in $T_1$, $T_2$ and $T_3$ treatments were 73.58, 68.97 and 70.38 tons/ha/109 days, respectively ( Fig. 5 and Table 2). The highest average weight of tomato 1633.5±132.04 g (73.58 tons/ha/cycle) was measured in treatment $T_1$ which was higher than other treatments and the previous findings of Mazed *et al.* [11] who use potassium and obtained yield 65.96 tons/ ha. Present study showed higher tomato production using egg shell powder 1 kg / decimal in treatment $T_1$ than the other treatments. On the other hand, tomato production using egg shell powder 1.5 kg / decimal in treatment $T_2$ was less than the treatment $T_3$ (control) where egg shell powder was not used.

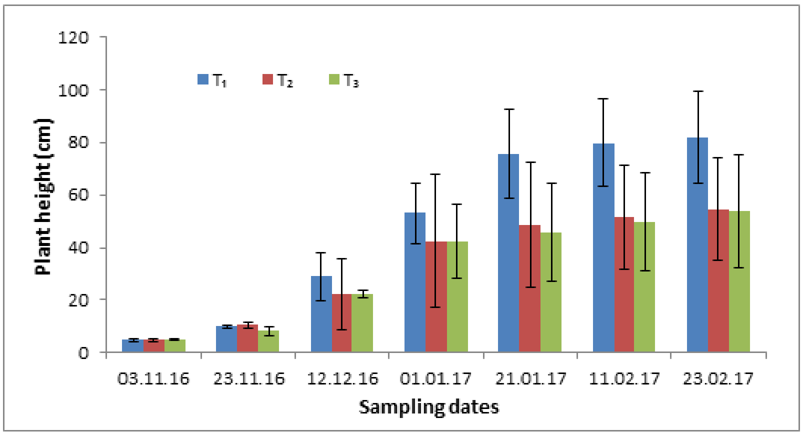


**Fig 3:** Height of tomato plant on different sampling dates. Vertical bar of each treatment represents standard deviations (±SD).

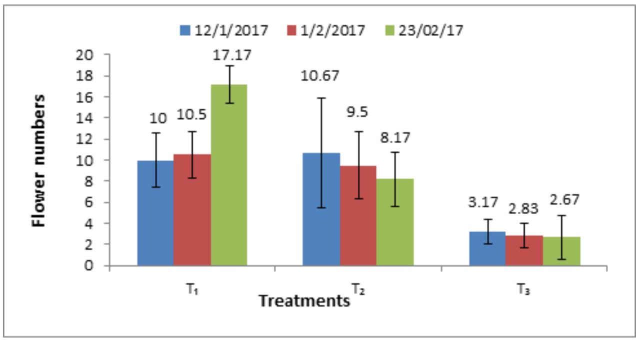


**Fig 4:** Flowers number at different sampling dates. Vertical bar of each dates represents standard deviations (±SD).

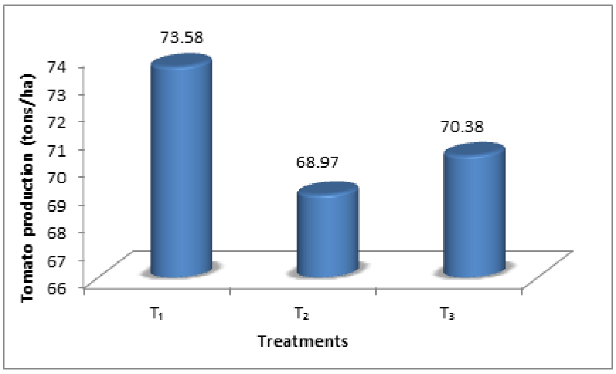


**Fig 5:** Tomato production in different treatments

**Table 2:** Growth parameters of plant in different treatments at harvesting date

| Date | Parameter | $T_1$ | $T_2$ | $T_3$ | Level of Significance |
|---|---|---|---|---|---|
| 23/02/2017 | total wt. of plant (g) | 164±46.16ª | 106.16 ±19.47ª | 101.83±16.91ª | NS |
| | Root wt.(g) | 54.5±10.13ª | 48±11.34ª | 46.5±6.7ª | NS |
| | Root length (cm) | 36.33±5.68ª | 27.5±4.505ª | 26.83±5.197ª | NS |
| | Fruit number | 25.0±2.73ª | 27.0 ±2.36ª | 23.66±2.94ª | NS |
| | Total fruit wt.(g) | 1633.5±132.04ª | 1531.16±215.60ª | 1562.5±127.49ª | NS |

NS indicates Non-significant; $T_1$=Treatment 1 (with 1 kg/decimal egg shell powder addition), $T_2$=Treatment 2 (with 1.5 kg/decimal egg shell powder addition) and $T_3$= control (no egg shell powder is added).

**Proximate composition of tomato**

According to USDA National Nutrient Database for Standard Reference, Basic Report 11529 [12] on tomato the proximate composition found moisture 94.52%, ash 0.53%, crude fiber 1.2%, crude protein 0.88%, crude fat 0.20% and carbohydrate 3.89%. In the present experiment proximate composition analysis of tomato samples was found highest lipid, ash, crude fiber and moisture, respectively 0.28±0.065, 0.67±0.20, 1.66±0.09 and 95.59± 0.57% in treatment $T_1$ which was higher thanUSDA National Nutrient Database for Standard Reference, Basic Report 11529 [12] on tomato (Table 3 and Fig. 6).On the other hand, Moisture 94.5±0.6, fiber 0.53±0.06, fat 0.090±0.014 was found by Martin-Belloso and Llanos-Barriobero [13] which were less than the present experiment. Egg shell powder addition in present experiment may be the cause of it.

**Table 3:** Proximate composition (% moisture basis) of tomato found at different treatments

| Treatment | Protein | Lipid | Ash | Crude fiber | Carbohydrate | Moisture |
|---|---|---|---|---|---|---|
| $T_1$ | 0.56±0.112ª | 0.28 ±0.065ª | 0.67±0.20ª | 1.66±0.09ª | 1.23±1.01ª | 95.59±0.57ª |
| $T_2$ | 0.75±0.005ª | 0.19±0.005ª | 0.57±0.08ª | 1.63±0.015ª | 1.39±0.08ª | 95.44±0.030ª |
| $T_3$ | 0.59±0.036ª | 0.16±0ª | 0.59±0.09ª | 1.61±0.08ª | 2.32±1.31ª | 94.72±1.22ª |

$T_1$=Treatment 1 (with 1 kg/decimal egg shell powder addition), $T_2$=Treatment 2 (with 1.5 kg/decimal egg shell powder addition) and $T_3$= control (no egg shell powder is added).

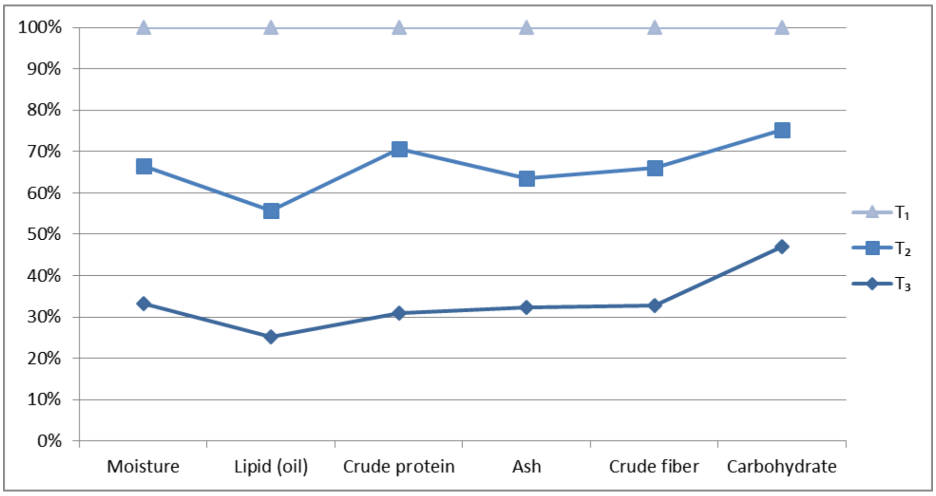


**Fig 6:** Proximate composition of tomato found at different treatments

**Water quality parameters**

It is reported that the fish species tilapia is known to be disease-resistant and tolerant to large fluctuations in pH value and water temperature. Stark [14] stated that large fluctuations in temperature and pH might harm fish, plants, and nitrifying microorganisms. Highest and lowest mean temperature value was found 25.43±0.321 and 20.6±0.115° C in treatment $T_1$and$T_3$, respectively. Acceptable growth for tilapia is at higher temperature at above 25 ˚C and optimal growth is at 27-29 ˚C suggested by Delong *et al.* [15]. So, the temperature obtained in current experiment remains within the range of previous findings (Fig.7). On the other hand, the present experiment showed suitable water temperature range according to Mirea *et al.* [16] which is 20-30 °C for intensive tilapia culture.

On the other hand, the highest pH value 9.19±0.065 was obtained in the treatment $T_2$, whereas the lowest value of pH obtained 8.93±0.017 in treatment $T_3$ on 22nd February, 2017 is in conformity with the finding of MacAndrew [17] which suggested best growth performance of tilapia between pH 7.0 and 9.0.Tyson *et al.* [18] stated that the optimum pH range for nitrification is 7.0 to 9.0 which indicates suitable pH range in present experiment (Fig.7).

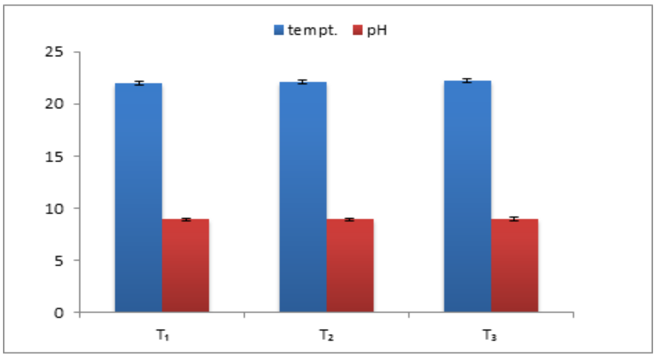


**Fig 7:** Mean values of temperature and pH during the study period. Vertical bar of each treatment represents standard deviations (±SD).

**Water quality lab test**

Highest electric conductivity (EC), hydrogen carbonate ($HCO_3$) and sulfur (S) 898±80.983μs/cm, 283.83± 21.035 and 4.421±0.233 mg/l, respectively found in treatment $T_3$ and carbonate (CO3), total nitrogen (Total-N), phosphorus (P), potassium (K), sodium (Na), respectively found as23.66±0.577, 4.2±0, 0.218±0.117, 0.807±0 and 70.156±4.052mg/l in treatment $T_2$at the beginning of the experiment (Table. 4). On the other hand, highest hydrogen carbonate ($HCO_3$) and total nitrogen (Total-N), respectively 381±14.396 and 7.2±0.081 mg/l was found in treatment $T_1$ at the end of the experiment (Table. 4). These findings were more or less similar to the previous finding of Salam *et al.* [6].

$CO_3$ was found 15±3, 23.66±0.577 and 16.66±9.451 in treatment $T_1$, $T_2$ and $T_3$, respectively at the initial water sample which was totally absent at the end of the experiment (Table. 4). On the other hand, gradual increase of $HCO_3$ was found in the experiment.

Total nitrogenwas found in range of 2.033±0.709 to 7.2±0.081 (mg/L) throughout the experiment which was higher than the findings of Rakocy *et al.* [19] in basil production (1.6-2.9 mg/L).This might cause higher mortality of fish in present experiment.

EC indicates dissolved salts in a given sample. The present study showed that the mean value of EC was 799±29.461, 831±35.51 and 898±80.983 at the beginning and it was 987± 46.93, 1128.66±144.34 and 1134±132.917in $T_1$, $T_2$ and $T_3$, respectively the end of the experiment. Gradual increase of EC was found in present experiment which might be due to egg shell powder addition in plant is in conformity with the finding of Fatema *et al.* [20].

**Table 4:** The water quality parameters of lab test results in different treatments during the experimental period

| Elements | Initial | | | Final | | |
|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_1$ | $T_2$ | $T_3$ |
| EC μs/cm | 799 ± 29.461 | 831±35.51 | 898 ± 80.983 | 987 ± 46.93 | 1128.66 ± 144.34 | 1134 ± 132.917 |
| $CO_3$ (mg/l) | 15 ± 3 | 23.66±0.577 | 16.66 ± 9.451 | Absent | Absent | Absent |
| $HCO_3$ (mg/l) | 271.93 ± 18.832 | 258.26±3.493 | 283.83 ± 21.035 | 381 ± 14.396 | 348.33 ± 27.13 | 366.36 ± 26.215 |
| Total-N (mg/l) | 2.033 ± 0.709 | 4.2±0 | 3.266 ± 0.808 | 7.2 ± 0.081 | 3.66 ± 2.94 | 6.366 ± 0.709 |
| P (mg/l) | 0.144 ± 0.145 | 0.218±0.117 | 0.213 ± 0.072 | 0.483 ± 0.534 | 1.57 ± 1.089 | 1.705 ± 0.611 |
| K (mg/l) | 0.706 ± 0.101 | 0.807±0 | 0.537 ± 0.116 | 0.486 ± 0.105 | 1.116 ± 1.305 | 0.91 ± 0.466 |
| S (mg/l) | 3.759 ± 0.189 | 4.249±0.067 | 4.421 ± 0.233 | 3.785 ± 0.648 | 4.02 ± 1.495 | 5.106 ± 0.187 |
| Na (mg/l) | 66.166 ± 2.904 | 70.156±4.052 | 69.14 ± 10.505 | 77.826 ± 20.05 | 77.146 ± 19.29 | 90.066 ± 9.996 |

NS indicates Non-significant; $T_1$=Treatment 1 (with 1 kg/decimal egg shell powder addition), $T_2$=Treatment 2 (with 1.5 kg/decimal egg shell powder addition) and $T_3$= control (no egg shell powder is added).

**Conclusion**

Egg shell is very available and cheap and its use in present experiment showed suitable result. In the present study tomato plant growth such as plant height, fruit number, flower number and production was found higher in treatment $T_1$ where egg shell powder was used at the rate of 1 kg/decimal than the other treatment. It also contributed in nutrient density in the fruit than the control. At present experiment no Blossom-end rot (BER) disease was found as it is very frequent. Although the egg shell contributed in higher production and nutrient density in tomato, it is necessary to carry out the experiment with wide range of egg shell application to confirm the result before releasing among the farmers.

**References**


1. Salam MA, Hashem S, Asadujjaman M, Li F. Nutrient Recovery from in Fish Farming Wastewater: An Aquaponics System for Plant and Fish Integration. World Journal of Fish and Marine Sciences. 2014; 6(4):355-360.
2. Dygert JP, Morris ML, Messick EM, Browning PH. Feasibility of an energy efficient large-scale aquaponic food production and distribution facility. In ASME 2014 8th International Conference on Energy Sustainability collocated with the ASME 2014 12th International Conference on Fuel Cell Science, Engineering and Technology. American Society of Mechanical Engineers. 2014; 3(6):1-13.
3. Fake C. Managing Blossom-End Rot in Tomatoes and Peppers. 2010; 31-040C:1-4.
4. Ho LC, Belda R, Brown M, Andrews J, Adams P. Uptake and transport of calcium and the possible causes of blossom-end rot in tomato. Journal of Experimental Botany.1993; 44(2):509-518.
5. Butcher GD, Miles. Concepts of eggshell quality. 1990; VM01300. PDF, 6.
6. Salam MA, Jahan N, Hashem S, Rana KM. Feasibility of tomato production in aquaponic system using different substrates. Progressive Agriculture. 2015; 25:54-62.
7. Rahmatullah R, Das M, Rahmatullah SM. Suitable stocking density of tilapia in an aquaponic system. Bangladesh Journal of Fisheries Research. 2010; 14(1-2):29-35.
8. Quagrainie K, Ngugi CC, Macharia S, Mwihaki KG. Assessment of Integrated Pond-Cage System for the Production of Nile Tilapia for Improved Livelihood of Small-Scale Fish Farmers in Kenya. Technical reports of Kenya, 2011.
9. Jahan N. Tomato (*Solanum lycopersicum*) production in aquaponic system in different media. MS Thesis, Department of Aquaculture, Bangladesh Agricultural University, Mymensingh, 2014.
10. Cole JC, Smith MW, Penn CJ, Cheary BS, Conaghan KJ. Nitrogen, phosphorus, calcium, and magnesium applied individually or as a slow release or controlled release fertilizer increase growth and yield and affect macronutrient and micronutrient concentration and content of field-grown tomato plants. Scientia Horticulturae. 2016; 211:420-430.
11. Mazed HK, Akand MH, Haque MN, Pulok MAI, Partho SG. Yield and economic analysis of tomato (*Lycopersicon esculentum* Mill.) as influenced by potassium and stem pruning. International Journal of Scientific and Research Publications. 2015; 5(1):1-5.

12. SR28, USDA. National Nutrient Database for Standard Reference, Release 28. US Department of Agriculture, Agricultural Research Service, Nutrient Data Laboratory, 2016. http://www. ars. usda. gov/ba/bhnrc/ndl. Accessed, 26.
13. Martin-Belloso O, Llanos-Barriobero E. Proximate composition, minerals and vitamins in selected canned vegetables. European Food Research and Technology. 2001; 212(2):182-187.
14. Stark JM. Modeling the temperature response of nitrification. Biogeochemistry. 1996; 35:433-445.
15. Delong DP, Losordo TM, Rakocy JE. Tank culture of tilapia. Southern regional aquaculture Center. 2009; 282:8.
16. Mirea C, Cristea V, Grecu IR, Dediu L. Influence of different water temperature on intensive growth performance of Nile tilapia (*Oreochromis niloticus*) in a recirculating aquaculture system. Lucrari Stiintifice-Seria Zootehnie. 2013; 60:227-231.
17. McAndrew BJ, Turner GF, Robinson RL, Beveridge MCM, Baird DJ, Ross LG, *et al.* Tilapias: Biology and Exploitation. Springer: Heidelberg, The Netherlands. 2000, 508.
18. Tyson RV, Simonne EH, White JM, Lamb EM. Reconciling water quality parameters impacting nitrification in aquaponics: the pH levels. In Proceedings of the Florida State Horticultural Society. 2004; 117(79):79-83.
19. Rakocy JE, Shultz RC, Bailey DS, Thoman ES. Aquaponic production of tilapia and basil: comparing a batch and staggered cropping system. Acta Horticulture. 2004; 648:63-69.
20. Fatema, UK, Salam MA, Rana KMS. Feasibility of coconut coir and water hyacinth roots as media in vertiponics system to grow mint. International Journal of Agriculture and Environmental Research. 2017; 3(3):3229-3245.