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Production Potential of Broccoli (*Brassica oleracea* var. *italica*) in Hydroponics and Tilapia Based Aquaponics

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Abstract

Hydroponics is a plant growing procedure in water and aquaponics is an eco-friendly, water and energy-saving bio-integrated recirculating aquaculture system that integrates fish farming and vegetable gardening in a symbiotic close loop system. This experiment was carried to observe the production potentiality of broccoli in different type hydroponics like organic hydroponics (T_1), inorganic hydroponics (T_2) and tilapia based aquaponics systems (T_3) each with three replicates for 106 days from 19th February to 4th June, 2018. Three kg vermicompost as T_1 was soaked in 90 L water in a drum with a net bag and after that 1 kg vermicompost was added weekly discarding the old one. In case of T_2, 28.50 g mixed fertilizer composed of 5g urea, 7.50g TSP, 5g MOP, 5g dolomite, 5g DAP, 0.50 g boron and 0.50 g iron were added in 90 L water and after seven days 22.80 g was added fortnightly. In the aquaponics tank, 10 healthy tilapia fingerlings were released in the same amount of water and 30% protein containing commercial floating feed was fed twice daily at the rate of 3% body weight. Sampling were carried out fortnightly for collecting different parameters of broccoli, fish and water quality. Significantly ($P \leq 0.01$) the highest broccoli production was found in T_2 (11.79±0.51 tons/ha/106 days) followed by T_3 (4.77±0.85 tons/ha/106 days) and the least was in T_1 (2.24±0.14 tons/ha/106 days). The analysis showed that, the leaf area, root length and weight were statistically similar in all the three treatments. Fish production was 21.55±3.36 tons/ha/106 days. Nutritional composition of broccoli was also highest in T_2 except moisture and ash content. Water dissolved oxygen, electrical conductivity, ammonia, nitrate, nitrogen and phosphorus concentration were suitable for growing broccoli in T_2. Whereas in T_3, ammonia concentration was high for fish. Broccoli production at higher temperature (31.40 to 36.00°C) in the laboratory than the optimum temperature was possible. Further experiment is needed to carry out in larger areas with different crops and fishes before extension in the field level.

Introduction

Bangladesh is pre-eminently an agrarian country. Various natural calamities like cyclone, drought and flood hamper its food production and cause fluctuation in supply round the year (Majumder, 2013). Hydroponics and aquaponics can be possible solution to the problems and using these techniques crops without soil can be grown. Hydroponics is the process of growing plants in water or nutrient solutions (Pandey *et al.*, 2009; Sardare and Admane, 2019) in a liquid nutrient solution with or without the use of artificial media. Water is supplemented with plants macro and micronutrients in hydroponics such as nitrogen, calcium, potassium, sodium, magnesium and iron (Téllez and Merino, 2012; Lazar *et al*., 2015). By contrast, aquaponics is a closed loop food production system combining hydroponic crop production with recirculating aquaculture (Shafahi and Woolston, 2014; Schmautz *et al.*, 2016). In this process, dissolved waste products are filtered and used by plants as a nutrient source and thus the system performs like the natural ecosystem (Timmons *et al*., 2002; Yildiz *et al.*, 2017; Lennard and Goddek, 2019). Broccoli (*Brassica oleracea* var. *italica*) is a cruciferous cool (18 to 24°C) season crop which is very popular throughout the world (Tindall, 1992). It is consumed both fresh and ripe but also as processed and is rich in- vitamin A, vitamin C, riboflavin, iron, calcium and other nutrients necessary for strengthening innate immune system (Nasr and Ragab, 2000; Wadmare *et al.*, 2019). Moreover, tilapia (*Oreochromis niloticus*) is one of the most common

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fishes used in aquaponics and can withstand a wide range of environmental condition.

Fertilizers are important source of plants nutrients which can be used as a solution in hydroponics. Vermicompost is a nutrient rich low-cost organic fertilizer which contains most of the nutrients such as- nitrates, phosphates, exchangeable calcium and soluble potassium which plants can easily absorb (Orozco *et al.*, 1996; Edwards, 1998). Chemical fertilizers are also widely used for growing plants. But, in hydroponics a single fertilizer is not enough for growing plants (Ikeda and Tan, 1998). Mixed fertilizer contains more than one primary nutrients such as- MAP, DAP, potassium, nitrate, ammonium and sulphate those are essential for plants growth (White, 2006) and these are seldom used in hydroponic culture. Higher yields can be achieved using mixed fertilizers over a single fertilizer (Islam *et al.*, 2017). Vermicompost and fish waste are effective for producing organic vegetables through the techniques. Little research has been conducted on the utilization of mixed fertilizer and vermicompost as sources of nutrients for hydroponic culture of vegetables. The study was carried out to compare broccoli yield, plant growth, proximate composition of broccoli and plants and water quality variation in organic hydroponics using vermicompost, inorganic hydroponics using mixed fertilizer and tilapia based aquaponics system. In addition, feasibility of producing broccoli in higher temperature than the optimum temperature was also studied.

Materials and Methods

Study site

The experiment was carried out in the "BAU Aquaponics Oasis" Laboratory, Department of Aquaculture, Faculty of Fisheries, Bangladesh Agricultural University (BAU), Mymensingh. It is situated at latitude 24°43′34″ and longitude 90°26′05″. The duration of the experiment was 106 days from 19th February to 4th June, 2018.

Experimental design

The experimental design was comprised of nine half drums, three containing vermicompost solution as organic hydroponics, three containing mixed fertilizer solution called inorganic hydroponics and three fish holding drums, respectively. Moreover, nine plastic jerry canes for broccoli growing bed, plastic pipes, nine aerators and irrigation pumps for each replication were used. Area of a half drum and vegetable bed were 0.26 and 0.11 m^2, respectively. Three treatments were denoted as T_1, T_2 and T_3. Each treatment had three replications and were arranged in randomized block design (RBD). The hydroponics as well as fish tanks were kept open.

All the half drums were filled with 90 L water. After plantation, 12-watt submergible pump was used to irrigate fish tank water and hydroponic solution to the vegetable growing beds from 9 AM to 5 PM (Fig. 1). However, aeration was continued for 24 hrs. in each tank up to the end of the experiment.

Setting up hydroponics and aquaponics systems

At first, 3 kg vermicompost was taken into a double folded nylon net and shaped into sack and hang from a bamboo stick into the half drum water. After 10 days, old vermicompost was discarded and 1 kg vermicompost was added in each week until the end of the experiment. In T_2, mixed fertilizers such as urea, TSP, MOP, dolomite, DAP, boron and iron at 5, 7.50, 5, 5, 5, 0.50 and 0.50 g was added in 90 L water, respectively. After that 80% of the initial weight of fertilizer (22.80 g) was added fortnightly. Ten healthy tilapia fingerlings with mean initial length of 11.61±0.93 cm and weight of 33.71±3.92 g were released into aquaponics tank (T_3). Fish was fed with commercial floating feed containing 30% protein twice daily at 9 AM and 5 PM up at the rate of 3% body weight.

Media bed preparation and planting broccoli

Nine plastic jerry canes were used as broccoli bed. One side of the 35 L cane was cut and shaped it like a baby bath tub. A hole of ¾" was made at the bottom of each bed to drain the water from the bed to the fish and hydroponics tanks keeping little water at the bottom for the plants. A stand pipe with several holes was set at one corner of the bed to collect and easily drain the water through a pipe. The broccoli bed was filled with 5 to 7 cm size brick-lets after washing. Two broccoli saplings were planted in equal distance in each bed.

Sampling and harvesting broccoli

Plant height, leaf number and leaf area were measured fortnightly. A hand held measuring tape was used to measure the plant height, leaf length and width. Leaf area was measured by multiplying the length and width of the leaf. The chlorophyll content of broccoli leaf was measured with a 'SPAD 502 Plus Chlorophyll Meter' fortnightly. The broccoli was harvested when matured and weighed with an electric balance. At the end of the experiment, all the plants were uprooted carefully from the bed and root of the plants were cut from the stem by a sharp knife and length and weight of plant and root were measured. Proximate composition such as- moisture, crude protein, crude lipid, crude fiber, ash and NFE (nitrogen free extract) of broccoli and plants were measured following AOAC (2019) method in the Fish Nutrition Laboratory, Department of Aquaculture, BAU, Mymensingh.

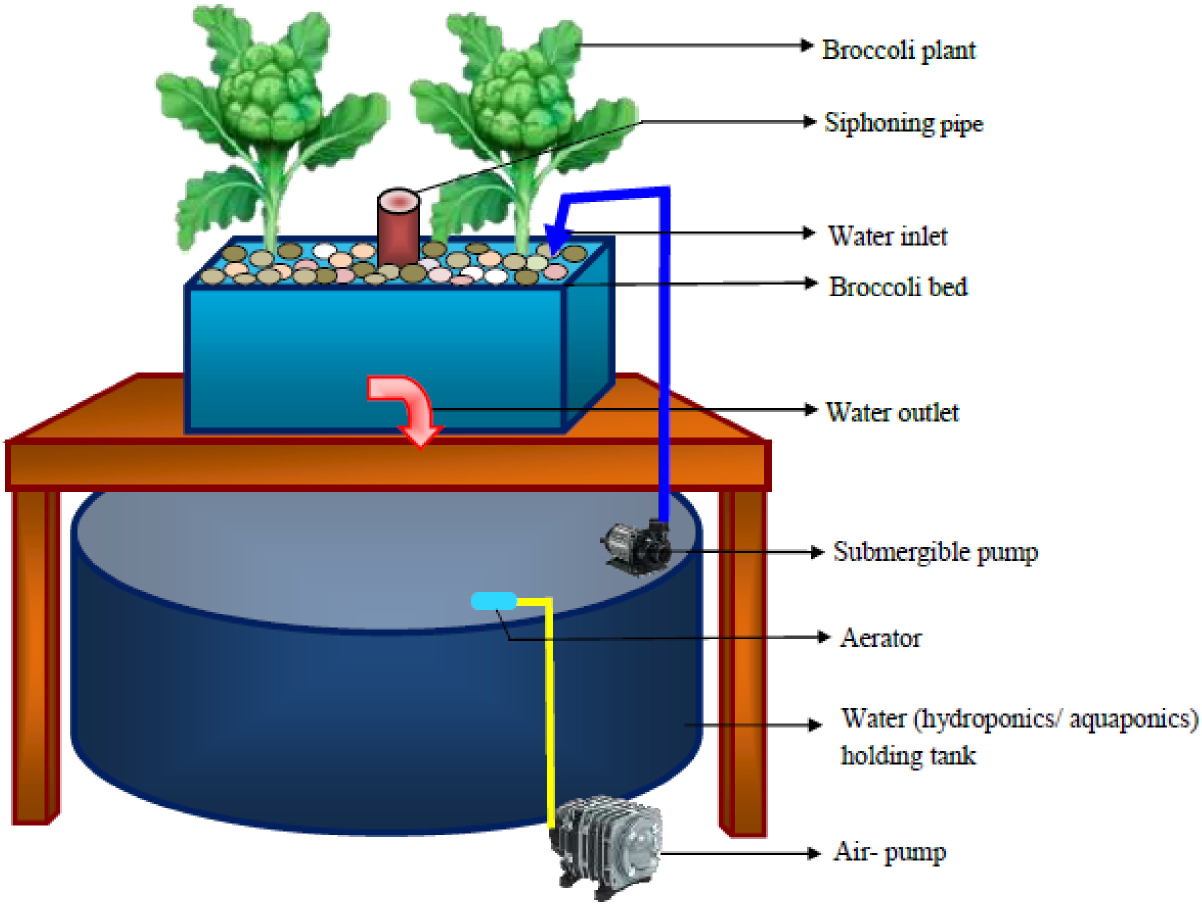

Figure 1. Layout of a typical hydroponics and aquaponics set-up used in the hydroponics and aquaponics systems

Sampling and harvesting fish

Fish sampling was done fortnightly. All the fishes were caught by a scoop net from the fish tank and length and weight of individual fish were measured. After completion of the experiment all the fishes were caught and survival rate, feed conversion ratio (FCR), length gain, weight gain, specific growth rate (SGR) and fish production were calculated.

Water quality parameters

Dissolved oxygen (DO), pH and temperature of tank water were measured with hand held DO meter, pH meter and thermometer, respectively. Whereas, ammonia, nitrite, and nitrate were measured with 'API Freshwater Master Test Kit' fortnightly. Moreover, electrical conductivity (EC) was measured with hand held EC measuring meter and other nutrients such as- sodium (Na), potassium (K), carbonates (CO_3^{2-}), hydrogen carbonates (HCO_3^-), total nitrogen (N), sulphur (S) and phosphorus (P) were measured in the 'Humboldt Soil Testing Laboratory' Department of Soil Science, BAU, Mymensingh three times during experiment.

Data processing and analysis

All the collected data were loaded in the computer using Microsoft Excel version 2013. Data analysis was performed using SPSS (Version 16.00) software, with an alpha set at 0.05 (significance at P<0.05) and the data were tested with one-way ANOVA and Duncan's Multiple Range Test (DMRT) was used to compare the means to show the significant differences between the treatments.

Results

Broccoli growth performances and production

The highest mean plant height, leaf number and leaf area of broccoli were observed (73.90±8.51 cm, 34.33±4.13 and 444.29±176.46 cm^2, respectively) in T_2 (Fig. 2; Fig. 3; Table 1). On the other hand, moderate mean plant height, leaf number and leaf area were observed in T_3 and the least mean plant height, leaf number and leaf area were found in T_1 where vermicompost leach was used. The similar trend was also found with chlorophyll content in broccoli leaf as well, where the SPAD readings were 60.31±4.03, 57.70±2.07 and 43.46±10.07 in T_2, T_3 and T_1, respectively those were significantly different (Fig. 4). After harvest, the broccoli plant weight and broccoli production in all the treatments were highly significantly different ($P \leq 0.01$) (Table 2). On the other hand, the mean root length and weight were not significantly different among the treatments (Table 2). The highest protein, lipid, fiber and NFE of broccoli were 4.54±0.52, 0.45±0.07, 6.47±0.01 and 1.29±0.22 %, respectively found in T_2 (Table 3). Moreover, moisture, protein, lipid, fiber, ash and NFE content range in plants were 86.20±0.63-86.86±0.45, 2.28±0.01-2.66±0.11, 0.44±0.05-0.49±0.08, 6.57±0.47-6.77±0.60, 2.84±0.05-2.95±0.21 and 0.96±0.18-1.01±0.11 %, respectively. The protein contents of plant and broccoli in three treatments were significantly and other components were not significantly different.

Tilapia growth and production

The initial mean length, final mean length and mean length gain of tilapia were 11.61±0.93, 16.35±1.07 and 4.74±0.67 cm, respectively (Fig. 5; Table 4). Moreover, the mean weight gain of fish was 32.44±1.21 g (Table 4). On the other hand, the specific growth rate, FCR and survival rate were 0.65±0.20 %, 3.2±0.11 and 86.66 %, respectively shown in Table 4. Whereas, tilapia production was achieved 21.55±3.36 tons/ha/106 days (Table 4).

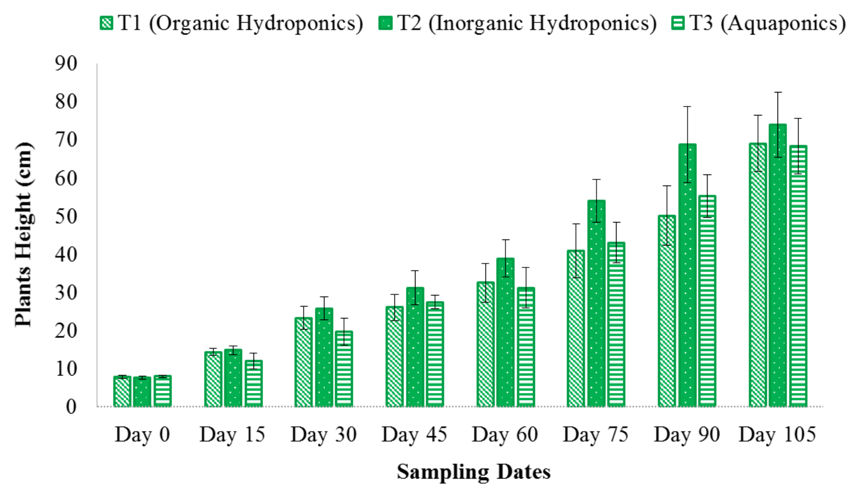

Figure 2. Plant height (cm ±SD) of broccoli in different sampling dates in hydroponics and aquaponics systems (vertical bar of each treatment represents the standard deviation)

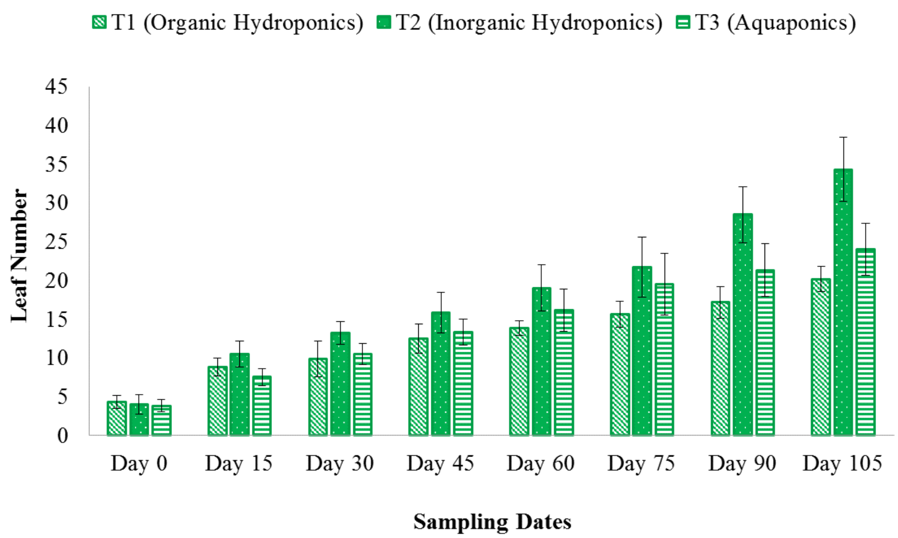

Figure 3. Leaf number (number ±SD) of broccoli in different sampling dates in hydroponics and aquaponics systems (vertical bar of each treatment represents the standard deviation)

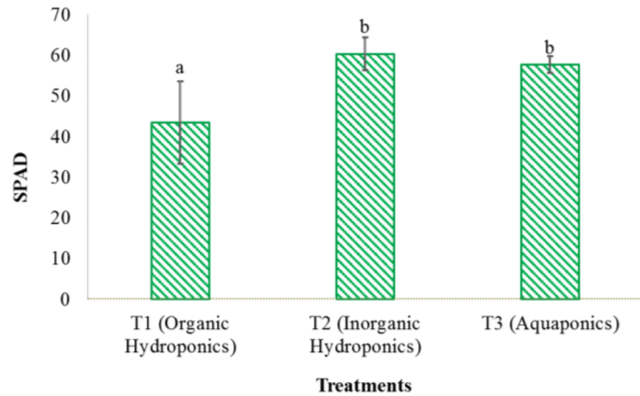

Figure 4. The leaf chlorophyll content (SPAD ±SD) of broccoli in hydroponics and aquaponics systems. Vertical bar of each treatment represents standard deviation and values in columns with different letters are significantly different at P<0.05.

Table 1. Variation of leaf area in three treatments in hydroponics and aquaponics systems

Sampling dates	Leaf area (cm^2)			Significance
	T_1	T_2	T_3	
Day 0	26.10±5.39	25.77±8.82	22.43±2.44	NS
Day 15	70.93±18.57	72.91±18.07	48.41±20.97	NS
Day 30	117.60±43.09	158.05±76.59	119.74±41.51	NS
Day 45	132.74±44.49	188.27±81.53	164.45±75.03	NS
Day 60	177.83±44.68	236.62±111.65	188.32±49.14	NS
Day 75	218.59±34.69	314.95±134.77	229.33±44.98	NS
Day 90	268.03±32.59	415.00±187.56	277.67±14.88	NS
Day 105	296.39±21.03	444.29±176.46	318.74±28.30	NS

T_1= Treatment 1 (organic hydroponics), T_2= Treatment 2 (inorganic hydroponics), T_3= Treatment 3 (aquaponics). In rows, NS means non-significance that indicates that P> 0.05. Values are mean±SD.

Table 2. Plant weight, root length, root weight and production of broccoli in hydroponics and aquaponics systems

Parameters	T1	T2	T3	Significance
Plants weight (g)	257.60±44.07a	601.99±168.26b	369.05±214.62a	**
Root length (cm)	18.50±4.28	27.33±5.89	24.83±7.68	NS
Root weight (g)	32.43±21.40	62.59±48.83	25.15±8.40	NS
Broccoli production (t/ha/106 d)	2.24±0.14a	11.79±0.51c	4.77±0.85b	**

T_1= Treatment 1 (organic hydroponics), T_2= Treatment 2 (inorganic hydroponics), T_3= Treatment 3 (aquaponics). In rows, values with different letters are significantly different at P<0.05 applying Duncan's Multiple Range Test, ** indicates that significant at P≤0.01 and NS means non-significance that indicates that P>0.05. Values are mean±SD.

Table 3. Moisture, protein, lipid, fiber, ash content and NFE in broccoli and broccoli plant in hydroponics and aquaponics systems

Components		Percentage			Significance
		T1	T2	T3	
Moisture	Broccoli	88.75±0.41b	86.21±0.53a	87.89±0.40b	**
	Plant	86.86±0.45	86.20±0.63	86.26±0.17	NS
Protein	Broccoli	3.26±0.01a	4.54±0.52b	3.41±0.43a	*
	Plant	2.28±0.01a	2.66±0.11b	2.61±0.05b	**
Lipid	Broccoli	0.44±0.03	0.45±0.07	0.43±0.06	NS
	Plant	0.44±0.05	0.49±0.08	0.47±0.11	NS
Fiber	Broccoli	5.55±1.04	6.47±0.01	5.98±0.03	NS
	Plant	6.57±0.47	6.77±0.60	6.67±0.29	NS
Ash	Broccoli	1.18±0.18	1.04±0.03	1.30±0.10	NS
	Plant	2.84±0.05	2.93±0.15	2.95±0.21	NS
NFE	Broccoli	0.82±1.02	1.29±0.22	0.99±0.21	NS
	Plant	1.01±0.11	0.96±0.18	1.03±0.23	NS

T_1= Treatment 1 (organic hydroponics), T_2= Treatment 2 (inorganic hydroponics), T_3= Treatment 3 (aquaponics). In rows, values with different letters are significantly different at P<0.05 applying Duncan's Multiple Range Test, * indicates that significant at P< 0.05, ** indicates that significant at P≤ 0.01 and NS means non-significance that indicates that P> 0.05. Values are mean±SD.

Water quality parameters

In the present study, the room temperature of the laboratory was ranged from 31.40 to 36.00°C (Fig. 6), whereas, the highest and the lowest mean water temperature was 26.75±0.47 and 26.70±0.44°C in T_1 and T_3, respectively (Table 5). The recorded highest and the lowest pH value were 7.90±0.13 and 6.53±0.36 found in T_1 and T_2, respectively and significant variations among treatments were found (Table 5). The highest mean dissolved oxygen (DO) was 8.00±0.13 mg/L observed in T_2 during the present study. Moreover, the highest concentration of ammonia, nitrite and nitrate were observed 2.67±1.15, 2.13±1.03 and 27.92±12.84 mg/L, respectively in T_2 depicted in Table 5. The electrical conductivity (EC) was highly significantly different among the treatments on third sampling and the highest was also in T_2 (Table 6). The highest mean value of Na, K, CO_3^{2-} and HCO_3^- were found higher in T_1 than T_2 and T_3. The CO_3^{2-} concentrations were zero in first two samplings in all treatments (Table 6). On the other hand, gradual increase of HCO_3^- was observed in T_1 but decreased in the other treatments. At the end of the experiment, the mean highest and the lowest concentrations of total-nitrogen (N) were 5.63±2.40 and 4.23±0.06 mg/L in T_2 and T_1, respectively (Table 6). Moreover, the T_1 contained higher sulfur (S) concentration than the other treatments which might have contributed in lower broccoli production. The highest mean value of phosphorus (P) was found 44.83±3.11 mg/L in T_2 and the lowest was 8.12±1.16 mg/L observed in T_3 (Table 6).

Discussion

Broccoli growth performances and production

The highest broccoli plant height was 73.90±8.51 cm observed in T_2 among the three treatments (Fig. 2). Nitrogen is an important component for cell division and enlargement of cells in the apical meristem which enhances plant height (Purbajanti *et al*., 2019). Continuous supply of soluble mixed fertilizers in the water enhanced the nitrogen availability for plants which resulted in the highest plant height in T_2. Yadav *et al.* (2016) reported that broccoli plant height was 63.90 cm in vermicompost supplemented soil based cultivation. The number of leaves in all the treatments corroborated with the findings (16.00 to 28.60) of Yadav *et al.* (2016) but much higher than the findings (2.2 to 10) of Getachew *et al.* (2016) in traditional soil based broccoli culture. The recorded highest leaf area (444.29±176.46 cm^2) was also found in T_2 in the present experiment which was in agreement with the result of da Silva *et al.* (2016) who reported the highest leaf area 470.57 cm^2 of broccoli.

After harvest, fresh weights of plants were 257.60±44.07, 601.99±168.26 and 369.05±214.62 g in T_1, T_2 and T_3, respectively. The root length in the present experiment (18.50±4.28 to 27.33±5.89 cm) were more or less similar to the findings of Shapla *et al.* (2014), where they recorded the root length ranging from 20.50 to 25.30 cm. Getachew *et al.* (2016) found lower root length (11.13 cm) of broccoli planted in February than the present study. Roots length depends on available nutrients for root apical meristem (RAM) zone. In T_3, the nutrients available in fish tank influenced more effectively than the nutrients in T_1 for roots vertical growth (Table 2). However, the weight of the roots (25.15±8.40 to 62.59±48.83 g) were much higher in the present experiment than the findings of Shapla *et al.* (2014), where they obtained 19.40 to 23.00 g root weight only. In the present study, the mean root weight was comparatively higher in inorganic hydroponics than organic hydroponics and aquaponics systems. It might be due to the high concentration of fertilizers added in regular interval. But, mean root weight of T_1 was higher than T_3 which indicated that, the available nutrients in the vermicompost tea was more effective for roots mass growth or secondary root formation than T_3. Significantly higher mean chlorophyll content of broccoli leaf was found with T_2 than T_3 and T_1 (Fig. 4) and the values were corroborated with the findings of Mellgren (2008), where the researcher used moderate irrigation and supplement nitrogen fertilizer in broccoli production. The higher nitrogen application was responsible for chlorophyll content increase or greenness of the plant (Ambrosini *et al.*, 2015). So, the higher chlorophyll content in T_2 might be due to the presence of higher nitrogen inorganic fertilizers. In T_3, fish feed and waste were the main sources of nitrogen which resulted in higher chlorophyll content than T_1. The broccoli production in all the three treatments were 2.24±0.14, 11.79±0.51 and 4.77±0.85 tons/ha/106 days, respectively and the values were highly significantly ($P \leq 0.01$) different (Table 2). Whereas Almaliotis *et al.* (2007) reported broccoli production 3.15 to 14.42 tons/ha which was close to the present result. In the present study, the chemical fertilizers had the higher effect on broccoli growth performances than the vermicompost leach based hydroponics and aquaponics systems as mixed fertilizers results in higher production (Islam *et al.*, 2017). Moreover, Hafiz *et al.* (2015) produced 5.17 to 23.21 tons/ha broccoli using five genotypes and in the present study, such higher production might not be possible as the head quality of broccoli is influenced by temperature and hot climate decreases the growth rate of broccoli (Tindall, 1992; Santipracha, 2007; Getachew *et al.*, 2016).

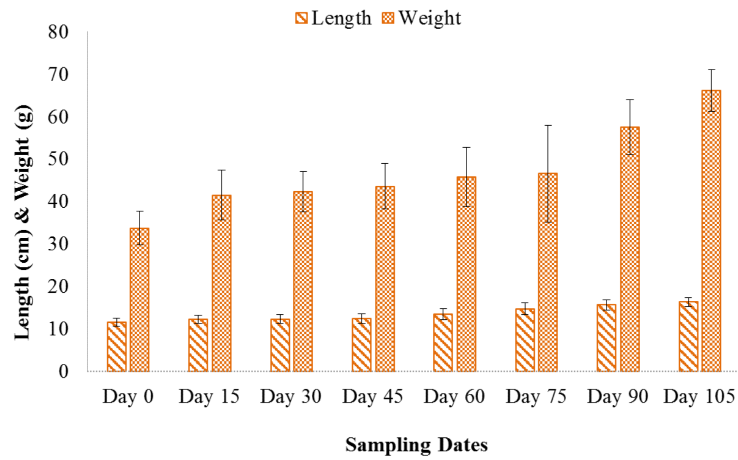

Figure 5. Length (cm ±SD) and weight (g ±SD) of tilapia in different sampling dates in the present hydroponics and aquaponics study (vertical bar of each treatment represents the standard deviation)

Table 4. Growth performances of tilapia in the hydroponics and aquaponics systems

Parameters	Value
Mean length gain (cm)	4.74±0.67
Percent length gain (%)	61.46±0.44
Mean weight gain (g)	32.44±1.21
Percent weight gain (%)	96.23±1.78
Specific growth rate (SGR)	0.65±0.20
Feed conversion ratio (FCR)	3.2±0.11
Survival rate (%)	86.66
Production (tons/ha/106 days)	21.55±3.36

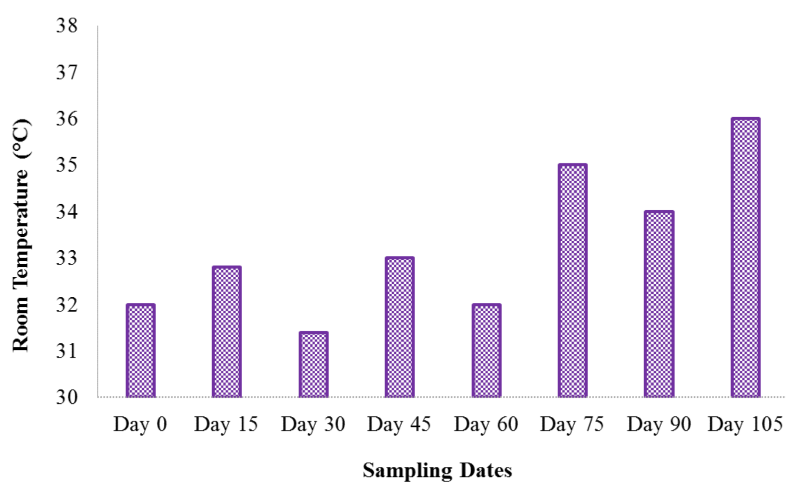

Figure 6. Room temperature (°C) in different sampling dates

Table 5. Mean water temperature (°C ±SD), pH (±SD), dissolved oxygen (DO), ammonia, nitrite and nitrate (mg/L ±SD) found in the hydroponics and aquaponics systems

Parameters	T_1	T_2	T_3	Significance
Temperature (°C)	26.75±0.47	26.71±0.46	26.70±0.44	NS
pH	7.90±0.13^c	6.53±0.36^a	7.16±0.16^b	**
Dissolved oxygen (mg/L)	7.88±0.15	8.00±0.13	7.89±0.15	NS
Ammonia (mg/L)	0.13±0.08^a	2.67±1.25^b	0.79±0.47^a	**
Nitrite (mg/L)	0.00±0.00^a	2.13±1.03^b	1.58±1.44^b	**
Nitrate (mg/L)	2.08±1.18^a	27.92±12.84^c	17.50±9.55^b	**

T_1= Treatment 1 (organic hydroponics), T_2= Treatment 2 (inorganic hydroponics), T_3= Treatment 3 (aquaponics). In rows, values with different letters are significantly different at $P<0.05$ applying Duncan's Multiple Range Test, ** indicates that significant at $P\leq 0.01$ and NS means non-significance that indicates that $P> 0.05$. Values are mean±SD.

Table 6. Electrical conductivity (EC) and other nutrients (Na, K, CO32-, HCO3-, N, S and P) in the hydroponics and aquaponics systems

Parameters	Sampling Dates	T_1	T_2	T_3	Significance
EC (µs/cm)	Day 0	747.00±0.00	747.00±0.00	747.00±0.00	-
	Day 53	1523.02±40.15^a	1939.11±119.87^b	1339.09±267.74^a	*
	Day 105	2093.13±92.92^b	3211.13±181.07^c	1469.07±113.21^a	**
Na (mg/L)	Day 0	109.25±0.00	109.25±0.00	109.25±0.00	-
	Day 53	355.30±10.69^c	295.07±40.51^b	164.01±4.96^a	**
	Day 105	401.50±40.91^c	313.07±21.52^b	108.93±3.81^a	**
K (mg/L)	Day 0	1.21±0.00	1.21±0.00	1.21±0.00	-
	Day 53	75.60±5.05^c	57.62±11.29^b	4.97±0.37^a	**
	Day 105	84.63±10.76^c	65.14±12.11^b	2.61±0.87^a	**
CO_3^{2-} (mg/L)	Day 0	0.00±0.00	0.00±0.00	0.00±0.00	-
	Day 53	0.00±0.00	0.00±0.00	0.00±0.00	-
	Day 105	59.33±6.11^b	11.67±11.06^a	2.00±3.46^a	**
HCO_3^- (mg/L)	Day 0	286.70±0.00	286.70±0.00	286.70±0.00	-
	Day 53	336.27±3.06^c	68.91±10.02^a	246.63±9.18^b	**
	Day 105	378.23±9.21^c	79.62±20.93^a	155.47±3.05^b	**
N (mg/L)	Day 0	2.80±0.00	2.80±0.00	2.80±0.00	-
	Day 53	0.77±0.71	3.20±3.29	1.50±1.41	NS
	Day 105	4.23±0.06	5.63±2.40	4.67±0.81	NS
S (mg/L)	Day 0	3.47±0.00	3.47±0.00	3.47±0.00	-
	Day 53	6.81±0.50	5.49±1.75	3.57±1.32	NS
	Day 105	11.97±0.68^b	4.72±2.99^a	3.39±0.80^a	**
P (mg/L)	Day 0	0.29±0.00	0.29±0.00	0.29±0.00	-
	Day 53	28.32±3.50^b	29.43±4.04^b	2.26±0.43^a	**
	Day 105	11.91±2.85^a	44.83±3.11^b	8.12±1.16^a	**

T_1= Treatment 1 (organic hydroponics), T_2= Treatment 2 (inorganic hydroponics), T_3= Treatment 3 (aquaponics). In rows, values with different letters are significantly different at $P<0.05$ applying Duncan's Multiple Range Test, * indicates that significant at $P< 0.05$ ** indicates that significant at $P\leq 0.01$ and NS means non-significance that indicates that $P> 0.05$. Values are mean±SD.

The proximate composition of broccoli, were in agreement with the findings of Wadmare *et al.* (2019), where they reported the moisture 86.36%, carbohydrate 5.59%, protein 4.89% and fat 0.37%. The highest values of proximate composition in the present experiment was in T_2 (Table 3) indicating the availability of nutrients for broccoli growth in the water than the other two treatments.

Tilapia growth and production

In the present study, the mean length gain of tilapia was 4.74±0.67 cm and percent length gain 61.46±0.44 % (Table 4). The percent length gain was higher than the findings of Akter *et al.* (2020) (28.91±4.53 %). However, the mean weight gain and percent weight gain were lower in the present experiment than the outcome of Afrin *et al.* (2018), where, they reported the weight gain of tilapia was 43.34±8.20 g after 105 days. Moreover, the specific growth rate (0.65±0.20 %) of the present experiment was lower than the findings of Fatema *et al.* (2017). In the present study, the FCR was 3.2±0.11 which was higher than the findings (2.73) of Salam *et al.* (2014). On the other hand, Akter *et al.* (2020) recorded FCR of tilapia 3.6 in control which was higher than the present experiment. The survival rate of tilapia was 86.66% in the present experiment and that was lower than the finding of Afrin *et al.* (2018). Moreover, the tilapia production (21.55±3.36 tons/ha/106 days) was in line with the finding of Akter *et al.* (2020) who obtained 19.55 ±1.56 to 26.27 ±2.47 ton/ta/60 days tilapia production . But the tilapia production was much lower (Table 4) than the findings (130 tons/ha/116 days) of Salam *et al*. (2014). Lower SGR, lower tilapia production and high FCR in the present experiment might be due to the experiment conducted at the end of the winter when fishes did not eat properly and feed wastage developed higher ammonia concentration in the fish tank resulting in slow growth response.

Water quality parameters

The highest and the lowest mean water temperature were reported in T_1 and T_3, respectively (Table 5). Optimum temperature for broccoli is 18 to 24°C (Tindall, 1992; Grevsen, 1998; Getachew *et al.*, 2016). The higher temperature might have affected the production of broccoli in the present study as more than 30°C temperature lower broccoli production (Warland *et al.*, 2006). However, the recorded temperature was within suitable range for tilapia, as Losordo *et al*. (1998) reported that, the optimum temperature for tilapia growth is 27 to 29°C. The pH range was not favorable for broccoli production and suitable pH for broccoli production is below 6.0 (Margareta, 2000). But, according to Maynard and Hochmuth (1997), the pH tolerance of plants ranges from 5.0 to 7.6 depending on species. The pH range of T_3 is in line with the findings of

Tyson *et al.* (2014) suggested that the best pH range for tilapia growth is 7.0-9.0. Dissolved oxygen (DO) in hydroponics and aquaponics is important for roots continuous respiration though plants roots can adjust with the lower oxygen (Goto *et al.,* 1996). The DO values recorded in the present study was corroborated with the findings of Afrin *et al.* (2018) on aquaponics system. Téllez and Merino (2012) mentioned that, the required oxygen solubility in hydroponics system are 8.26 and 7.56 mg/L, respectively in 25 and 30°C temperature. The mean values of ammonia, nitrite and nitrate were highest in T_2 and the lowest in T_1 (Table 5). Urea and DAP (Di-ammonium phosphate) contributed in T_2 for highest ammonia. According to Alexandrova and Jorgensen (2007), in aqueous solution urea decomposes into CO_2 and ammonia and the reaction depends on pH, temperature and microbial community in the water. DAP also decomposes into plants available ammonia and phosphate (Bolan *et al*. 2003). The ammonia concentrations obtained in the present experiment were higher than the maximum tolerable level agreed by Pillay and Kutty (2005) for fish culture in T_3 and uneaten feed was responsible for high ammonia. But the mean ammonia, nitrate and nitrite of T_3 was lower than T_2 and it might be due to nutrients loss, denitrification and ammonia volatilization (Neto and Ostrensky, 2015; Wongkiew *et al.*, 2017).

The EC level in T_1 and T_3 in the present study were below the threshold level except in T_2 for broccoli production (Jensen and Collins, 1985; Tanji and Wallender, 2012). The Na values were lower than the recommended values of Bittsánszky *et al*. (2016) for both hydroponics and aquaponics systems. The highest and the lowest total-nitrogen (N) concentration were 5.63±2.40 and 4.23±0.06 mg/L, found in T_2 and T_1, respectively (Table 6) which were lower than the recommendation of López *et al*. (2016) for hydroponics broccoli production. Though, in case of aquaponics, fish feces contains 10 to 40% N (Schneider *et al*., 2004), denitrification also can lead to a loss of 25-60% of the N depending on the presence and load of facultative heterotrophic bacteria in the tank (Eck *et al*. 2019, Zou *et al*. 2016). The highest P level was detected in T_2 (Table 6) and it might be due to TSP and DAP fertilizers inclusion in the solution of T_2. On the other hand, most of the nutrients recorded in T_3 were in agreement with the study by Afrin *et al.* (2018).

Conclusion

In the present study, the broccoli production was possible at high temperature (31.40 to 36°C) in all the treatments. Most of the growth parameters of broccoli, proximate composition and production were higher in inorganic hydroponics solution (T_2) followed by aquaponics (T_3) and organic hydroponics systems (T_1), respectively. Fish as well as broccoli production was satisfactory in aquaponics system where fish poo acted as fertilizer for broccoli production. Therefore, it can be concluded that the high nutrients and vitamins containing broccoli production is possible in organic hydroponics as well as in aquaponics systems even at higher temperature. So, further pilot study is needed to carry out in other areas with other potential indigenous crops and fishes with analyzing benefit-cost ratio before extension in the field level.

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Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Afrin, R., Rana, K.M.S., Islam, M.K., Zahan, S. and Salam, M.A. 2018. Cauliflower (*Brassica oleracea*) production incorporated with sea salt in aquaponic system. *European Journal of Biotechnology and Bioscience*, 6(2):5-11.

Akter, S., Bablee, A.L., Rana, K.M.S, Nigar, M., Nadia, Z.M. and Salam, M.A. 2020. Effects of foliar and root application of epsom salt on aquaponics beetroot (*Beta vulgaris*) production in confined condition. *Asian Journal of Medical and Biological Research*. 6 (1), 56-66. https://doi.org/10.3329/ajmbr.v6i1.46479

Alexandrova, A.N. and Jorgensen, W.L. 2007. Why urea eliminates ammonia rather than hydrolyzes in aqueous solution. *The Journal of Physical Chemistry B*, 111(4): 720-730. https://doi.org/10.1021/jp066478s

Almaliotis, D., Bladenopoulou, S., Chatzissavvidis, C.H. and Karagiannidis, N. 2007. Broccoli (*Brassica Oleracea* L. var. *italica*) yield as affected by soil fertility parameters in Northern Greece. *Acta Horticulture*, 729: 409-413. https://doi.org/10.17660/ActaHortic.2007.729.68

Ambrosini, V.G., Voges, J.G., Benevenuto, R.F., Vilperte, V., Silveira, M.A., Brunetto G. and Ogliari J.B. 2015. Single-head broccoli response to nitrogen application. *Científica*, 43(1): 84-92. https://doi.org/10.15361/1984-5529.2015v43n1p84-92

- AOAC, 2019. Association of Official Analytical Chemist, Official Methods of Analysis Association (21st Edition), Arlington, VA.

Bittsánszky, A., Uzinger, N., Gyulai, G., Mathis, A., Junge, R., Villarroel, M., Kotzen, B. and Komives, T. 2016. Nutrient supply of plants in aquaponic systems. *Ecocycles*, 2(2):17-20. https://doi.org/10.19040/ecocycles.v2i2.57

Bolan, N.S., Adriano, D.C. and Naidu, R. 2003. Role of phosphorus in (im)mobilization and bioavailability of heavy metals in the soil-plant system. *Reviews of environmental contamination and toxicology*, 177: 1-44. https://doi.org/10.1007/0-387-21725-8_1 da Silva, G.P., Prado, R.M., Júnior, G.B.S., Silva, S.L.O., Leal, F.T., Costa L.C. and Carmona V.M.V. 2016. Broccoli growth and nutritional status as influenced by doses of nitrogen and boron. *African Journal of Agricultural Research*, 11(20):1858-1861. https://doi.org/10.5897/AJAR2015.10546

Eck, M., Körner, O. and Jijakli, M.H. 2019. Nutrient Cycling in Aquaponics Systems. In: Aquaponics Food Production Systems, pp. 231-246. https://doi.org/10.1007/978-3-030-15943-6_9

Edwards, C.A. 1998. The use of earthworms in the breakdown and management of organic waste, Earthworm Ecology, CRC Press, Boca Raton, FL, USA. pp: 327-354.

Fatema, U.K., Salam, M.A. and Rana, K.M.S. 2017. Feasibility of coconut coir and water hyacinth roots as media in vertiponics system to grow mint. *International Journal of Agriculture and Environmental Research*, 3(3): 3229-3245.

Getachew, E., Abraham, E. and Melese, W. 2016. Growth response of broccoli (*Brassica oleracea*) to different planting date at Jimma South Western Ethiopia. *International Journal of Research – GRANTHAALAYAH*, 4(6): 110-118. https://doi.org/10.5281/zenodo.56632

Goto, E., Both, A., Albright, L., Langhans, R. and Leed, A. 1996. Effect of dissolved oxygen concentration on lettuce growth in floating hydroponics. *Acta Horticulture*. 440: 205-210. https://doi.org/10.17660/ActaHortic.1996.440.36

Grevsen, K. 1998. Effects of temperature on head growth of broccoli (*Brassica oleracea L.* var. *italica*): parameter estimates for a predictive model. *Journal of Horticultural Science and Biotechnology*, 73(2): 235-244.

Hafiz M.A., Biswas A., Zakaria M., Hassan J. and Ivy N. A. 2015. Effect of planting dates on the yield of broccoli genotypes. *Bangladesh Journal of Agricultural Research*. 40(3): 465-478.

Ikeda H. and Tan X. 1998. Urea as an organic nitrogen source for hydroponically grown tomatoes in comparison with inorganic nitrogen sources. *Soil Science and Plant Nutrition*, 44:4, 609-615. https://doi.org/10.1080/00380768.1998.10414484

Islam, M.A., Ferdous, G., Akter, A., Hossain, M.M. and Nandwani, D. 2017. Effect of organic, inorganic fertilizers and plant spacing on the growth and yield of cabbage. *Agriculture*, 7(31): 01-06. https://doi.org/10.3390/agriculture7040031

Jensen, M.H. and Collins, W.L. 1985. Hydroponic vegetable production. *Horticultural Reviews*, 7: 483-558. https://doi.org/10.1002/9781118060735.ch10.

Lazar, R., Lacatusu, R. and Rizea, N. 2015. The influence of water source for preparing the nutrient pollutions used for cucumbers irrigation in hydroponic greenhouse. *Research Journal of Agricultural Science*, 47(3): 97-102.

Lennard W. and Goddek S. 2019. Aquaponics: The Basics. In: Goddek S., Joyce A., Kotzen B., Burnell G. (eds) Aquaponics Food Production Systems. Springer, Cham, pp: 113-143. https://doi.org/10.1007/978-3-030-15943-6_5

López, G.S., Rangel, P.P., Chavez, E.S., Rivera, J.R.E., Hernández, M.F. and Reséndez, A.M. 2016. Organic nutrient solutions in production and antioxidant capacity of cucumber fruits. *Emirates Journal of Food and Agriculture*, 28(7): 518-521. https://doi.org/10.9755/ejfa.2016-01-083

Losordo, T.M., Masser, M.P. and Rakocy, J. 1998. Recirculating aquaculture tank production systems: An Overview of Critical Considerations. South Regional Aquaculture Center, 451:1-6.

Majumder, S. 2013. The Economics of Early Response and Resilience: Bangladesh Country Study, pp: 8.

Margareta, M. 2000. Soil pH and nutrient uptake in cauliflower *(Brassica oleracea L.* var. *botrytis)* and broccoli (*Brassica oleracea L*. var. *italica*) in Northern Sweden. Doctoral thesis, Department of Agricultural Research of Northern Sweden. Swedish University of Agricultural Sciences, Umea.

Maynard, D.N. and Hochmuth, G.J. 1997. Knotts handbook for vegetable growers, 4th Edition. John Wiley and Sons, Inc., New York. pp. 564.

Mellgren, R. 2008. Effect of irrigation and nitrogen treatments on yield, quality, plant nitrogen uptake and soil nitrogen status and the evaluation of sap test, spad chlorophyll meter and dualex to monitor nitrogen status in broccoli. Master thesis in the Horticultural Science Programme, Swedish University of Agricultural Sciences. ISSN 1403-0993.

Nasr, M.H.A. and Ragab, W.S.M. 2000. Yield, head quality and nutritional composition of a new late flowering broccoli variety grown under Assiut conditions. *Journal of Agricultural Science*. 31(1): 55-77.

Neto, M.R. and Ostrensky, A. 2015. Nutrient load estimation in the waste of Nile tilapia *Oreochromis niloticus* (L.) reared in cages in tropical climate conditions. *Aquaculture Research*, 46: 1309-1322. https://doi.org/10.1111/are.12280

Orozco, F.H., Cegarra, J., Trujillo, L.M. and Roig, A. 1996. Vermicomposting of coffee pulp using the earthworm *Eisenia fetida*: effects on C and N contents and the availability of nutrients. *Biology and Fertility of Soils*, 22(1-2): 162-166.

Pandey, R., Jain, V. and Singh, K.P. 2009. Hydroponics Agriculture: Its status, scope and limitations; pp. 20-29. http://www.researchgate.net/publication/259786326.

Pillay, T.V.R. and Kutty M.N. 2005. Aquaculture, Principles and Practices, 2nd Edition. Blackwell Publishing Ltd, Oxford, UK, pp: 630.

Purbajanti, E.D., Slamet, W., Fuskhah, E. and Rosyida. 2019. Effects of organic and inorganic fertilizers on growth, activity of nitrate reductase and chlorophyll contents of peanuts (*Arachis hypogaea* L.). *IOP Conference Series: Earth and Environmental Science*, 250: 012048. https://doi.org/10.1088/1755-1315/250/1/012048

Salam, M.A., Jahan, N., Hashem, S.H. and Rana, K.M.S. 2014. Feasibility of tomato production in aquaponic system using different substrates. *Progressive Agriculture*, 25: 54-62.

Santipracha, Q., 2007. Vegetable Crop Variety and Growing Season of Southern Thailand. 1st Edn., Text J. Publication, Bangkok, pp: 22.

Sardare, M.D. and Admane, S.V. 2019. A Review on Plant without Soil-Hydroponics. *International Journal of Research in Engineering and Technology*, 2(3): 299-304.

Schmautz, Z., Loeu, F., Liebisch, F., Graber, A., Mathis, A., Bulc, T.G. and Junge, R. 2016. Tomato productivity and quality in aquaponics: comparison of three hydroponic methods. *Water*, 8(11): 533. https://doi.org/10.3390/w8110533\.

Schneider, O., Sereti, V., Eding, E.H. and Verreth, J.A.J. 2004. Analysis of nutrient flows in integrated intensive aquaculture systems. *Aquaculture Engineering*, 32: 379-401. https://doi.org/10.1016/j.aquaeng.2004. 09.001.

Shafahi, M. and Woolston, D. 2014. Aquaponics: A Sustainable Food Production System. https://doi.org/10.1115/IMECE2014-39441.

Shapla, S.A., Hussain, M.A., Mandal, M.S.H., Mehraj, H. and Uddin, J. 2014. Growth and yield of broccoli (*Brassica oleracea* var. *italica*) to different organic manures. *International Journal of Sustainable Crop Production*, 9(2): 29-32.

Tanji, K.K. and Wallender, W.W. 2012. Agricultural salinity assessment and management (second edition). American Society of Civil Engineers.

Téllez, L.I.T. and Merino, F.C.G. 2012. Nutrient solutions for hydroponic systems, in hydroponics: A standard methodology for plant biological researches, Asao, T., Ed.; Pp. 1-20. In Tech: Rijeka, Croatia, pp: 1-20. https://doi.org/10.5772/37578

Timmons, M.B., Ebeling, J.M., Wheaton, F.W., Summerfelt, S.T. and Vinci, B.J. 2002. Recirculating aquaculture systems, 2nd edn. Cayuga Aqua Ventures, Ithaca.

Tindall, H.D. 1992. Vegetables in the tropics. The Macmillan Press ltd. London and Basingstoke.

Tyson, R. and Simmone, E.H. 2014. A practical guide for aquaponic as an alternative enterprise. University of Florida, Horticulture Department, UF/IFAS Extension document, HS1252.

Wadmare, V.B., Gadhe, K.S. and Joshi, M.M. 2019. Studies on physical and chemical composition of broccoli (*Brassica oleracea* L.).

International Journal of Chemical Studies, 7(2):825-828.

Warland, J., McKeown, A.W. and McDonald, M.R. 2006. Impact of high air temperatures on brassicaceae crops in southern Ontario. *Canadian Journal of Plant Science*, 86:1209-1215.

White, R.E. 2006. Principles and practices of soil science: The soil as a natural resource. 4th edition, Blackwell publishing; pp. 34-344.

Wongkiew, S., Hu, Z., Chandran, K., Lee, J.W. and Khanal, S.K. 2017. Nitrogen transformations in aquaponic systems: a review. *Aquaculture Engineering*, 76: 9-19. https://doi.org/10.1016/j.aquaeng.2017.01.004

Yadav, L.P., Singh, A. and Malhotra, S.K. 2016. Growth, yield and quality response of organic broccoli to intercrops and crop geometry. *Indian Journal of Horticulture*, 73(3): 376-382.

Yildiz, H.Y., Robaina, L., Pirhonen, J., Mente, E., Domínguez, D. and Parisi, G. 2017. Fish welfare in aquaponic systems: Its relation to water quality with an emphasis on feed and faeces. *Water*, 9(13): 2-17.

Zou, Y., Hu, Z., Zhang, J., Xie, H., Guimbaud, C. and Fang, Y. 2016. Effects of pH on nitrogen transformations in media-based aquaponics. *Bioresource Technology*, 210: 81-87. https://doi.org/10.1016/J.BIORTECH.2015.12.079