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Studies on the Integrated Aquaponic System with Green Herbal Cultivation by using Liquid Fertilizer of Seaweed, Turbinaria Conoides

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Abstract: Aquaculture is fast-growing industry because of major increases in for fish and seafood demands all over the world. Aquaponic system is re-circulating aquaculture system that integrates hydroponic production of plants. The aquaponic system was comprised of 139.59 liters of fish tank. The fishes were stocked at the rate of 20 Tilapia fingerlings. Water from the fish tank was flooded to the media bed (cocopeat) and then drained back in the sump tank. Vermicompost were converted from the organic waste using the non-burrowing earthworms, Eudrilus eugeniae. This system was analyzed by physical and nutritional parameters of aquaponic water, vermicompost and seaweed, Turbinaria conoides along with the estimates of morphological efficiency of herbal greens, Solanum nigrum. T. conoides seaweed was used to resolution the nutrient deficiency in the aquaponic water. The nutrient level in the aquaponic water and vermicompost were recorded as NO_3 (35 mg/l and 1.49mg/l), phosphate (10 mg/l: 17 mg/l), and potassium (27 mg/l: 287 mg/l), respectively. Calcium and Magnesium level in the aquaponic water and vermicompost were recorded as 34 mg/l and 14.2 mg/l, 49 mg/l and18 mg/l, respectively. The Iron and Zinc level in the aquaponic water and vermicompost were recorded as 0.2mg/l and 1.3 mg/l and 0.08 mg/l, and 0.18 mg/l, respectively. Plant height the total number of leaf area were highest in T3 on the 7th week and compare the T6 and lowest in the control T1.Fresh weight and dry weight of the trial were highest in T3 (92.40) followed by T6 (88.10) and least in T1 (78.70). The root: shoot ratio were highest at T3 (0.12) and compare the T6 (0.15) and least at T2 (0.22), T1 (0.26). The study reported that the higher growths were observed in the aquaponic water because continuous supply of nutrients to the plants along with the T.conoides seaweed extract has different effects on the growth of S. nigrum. Hence, in this present study is the simple practice of application of aquaponic water using seaweed as liquid fertilizers and were eco-friendly approaches is recommended to the farmers for attaining better growth and yield.

Keywords: Mediated Aquaponic system; Turbinaria conoides; Solanum nigrum; Eudrilus eugeniae; Nutritional Parameters

I. INTRODUCTION

Aquaponic and Hydroponics is a sustainable food production system that combines in a symbiotic environment while eradicate the drawback of both system. The fish consume food and produce waste product that serves as nutrient to the hydroponic system (Bethe, 2017). The water use in this system is efficient, fish and vegetable production is higher than the conventional aquaculture (Azad, 2015). Even though, conventional agriculture uses excess water, the Aquaponic use less than 10% of water, (Bernstein, 2011). Salam *et al*., (2013) revealed that Aquaponic is eco-friendly and stable food production system which can produce relatively safe food (fish and vegetables) with reduced environmental hazards. Because no artificial fertilizer and chemicals are used for vegetable production, fish waste act as nutrients for plants. In this system, plants are cultivated in soil-less media, there is no possibility of soil borne diseases, it prevent weeds and other pests from preventing plant growth.

Media-filled bed units are the most popular design for small-scale Aquaponic system that issued all over the world, especially India. In this system, plants are grown in the media where water from the fish tank supplied to the media filled growbed for plant absorption. Plants absorb the water and take nutrients (Rakocy, 1999) then the clean water returns to the fish tank. It eliminates the need of biofilter (Lennard and Leonard, 2006; McMurtry *et al*., 1997). The media is filled with coco peat. Tilapia has many favorable characteristics for aquaculture production. Tilapia can tolerate poor water quality, wide salinity ranges, water temperature ranges, low dissolved oxygen levels, and elevated ammonia concentrations have less effect on Tilapia. They are omnivorous; it has unique taste and less consumable value (Popma and Masser, 1999).

Solanum nigrum greens are cultured in Aquaponic water, it is also called 'Black night shade'. The leaves and small dark fruits are really good to taste and has immense medicinal value. The leaves have high medicinal value and are a very good source for the removal and cure of stomach and mouth ulcers. The Aquaponic water contains the 10 nutrients necessary for the plant growth after the bacterial activity. The micro and macro nutrients are in the limited level in some time it was based on the fish feed and feeding rate of the fishes. The three nutrients such as calcium, potassium and Iron are deficient in this system. The deficiency occur in the plants reduced the growth and yield (Bernstein, 2011). The lower nutrient concentrations are acceptable for Aquaponic system because the nutrients are produced daily with the fish metabolic activities (Gurel and Yusuf, 2010; Rakocy *et al*., 2004).

Turbinaria conoides is brown algae (Phaeophyceae) found primarily in tropical marine water. It generally grows on rocky substrates and abundantly grown in coastal seashore of South India. Seaweed extract is 100% natural, water-soluble, liquid organic bio fertilizer containing micro and macro nutrients, it also contains some of the plant growth promoting substances like Cytokinin, Gibberellins and Auxins and it is used as a fertilizer to attaining better germination, growth and yield(Crouch and Van Staden, 1993).Therefore, in this present study aimed to compensate the deficiency of Aquaponic water and examine the growth performance of *Solanum nigrum* plants in the *Oreochromis niloticus* (Tilapia) recirculation Aquaponic system with addition of *Turbinaria conoides* seaweed liquid fertilizer by foliar spray and compare it with the vermicomposting plant system.

II. MATERIALS AND METHODS

An Aquaponic system was designed based on the Bernstein, (2011) model. The Aquaponic system was comprised of a 139.59 liters fish tank should be covered with aluminum net. The tap water, which was located near the rearing tanks, supplied water from a short distance to the fish rearing tank. The conformity of nitrification and nutrient availability in Aquaponic system was acquired pH= 7. The fish tank was aerated with 10 watts air pump fitted with fish tank. The water from the fish tank was flowed by the gravity and then it was entered the hydroponics growbed. The pipes were plumped to join media-filled grow bed with the fish tank having inlet and outlet of water. An overflow pipe was set at 10cm for maintained a constant water level in the plant bed. The hydroponics media- filled growbed was filled with Aquaponic water; it was drained and entered in to the sump tank. The capacity of the sump tank was 20liters. The fishes were stocked at the rate of 20 Tilapia fingerlings of 2.5cm length and 4-6 gm of fishes for maintained at every 75 sq cm. in the fish tank.

A. *Plant and Seaweed Collection*

The Solanum nigrum plant seeds were collected at Agriculture University, Coimbatore, Tamil Nadu. The 50 healthy seeds were selected from the seed packet and 25 seeds were sprayed in the media-filled growbed because it was helped to measure the seed germination days. Equal height of the saplings were selected and bought from the Agri nursery, planted in each treatment grow beds after five weeks. The experimental seaweeds were collected from the coastal area of Mandapam, Ramanathapuram, Tamil Nadu, India (Latitude of 9° 17'N and Longitude of 80°10'E). Seaweed, Turbinaria conoides handpicked and washed thoroughly with seawater and tap water to remove unwanted impurities and dried. The seaweed was taxonomically identified at the Botanical Survey of India (BSI), Southern Regional Centre, Coimbatore, Tamil Nadu, India.

B. *Media filled grow bed*

Solanum nigrum were grown in tub containing coconut peat as a medium. After that, the plants were transferred in to growth bed components containing Aquaponic system. Media bed was filled with cocopeat were efficient with space, have a relatively low initial cost and also the same medium functions as a mechanical and biological filter.

Four media filled grow beds were chosen for plant cultivation (Bernstein, 2013), wooden frame with water-tight polyethylene sheeting on the base and inside the walls. The size of the media beds were 50 cm x 30 cm x 30 cm. The shape of the bed was rectangular. The water holding capacity of the four beds was 40 liters. The areas of the four media filled grow bed were 18 m^2, beds are designed to flood-and-drain.

Solanum nigrum plants were introduced into the growbed after the 7 days of fishes transferred in the fish tank. Then the saplings are placed to the grow bed by digging a small hole 2 inch deep in the grow media. In each media 15 plants were planted. The intervals of the each sapling were between 6 inches or 15 cm. The procedure was followed in the each media filled setups.

Figure 1. a denotes Seaweed, Turbinaria conoides and b denotes Solanum nigrum plant cultivation.

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C. Preparation of Vermicompost

Vermicompost was used in the present study was obtained by utilizing the African earthworm, *Eudrilus eugeniae* prepared as detailed by (Chauhan and Singh, 2013). The earthworm was bought in the vermicompost form of uniform size were selected at Pannimadai near Thudiyalur, Coimbatore, Tamil Nadu.

The agro waste was collected from Thudiyalur market. The bio degradable agro waste material was cut into small pieces, allowed to its partial decomposition for 10-15 days for achieving better activity of earthworm. Partially decomposed agro waste material was arranged in layers at the vermicompost project site. Three layer of partially bio degradable agro waste at the bottom of bed and two layer of cow dung slurry was applied on it to further decomposing of the agro waste for 20- 40 days. Moisture level should be maintained by sprinkling water. Bio waste and cow dung ratio must be 60:40. The layer was obtained as black color. The red soil was collected from the culturing site. The red soil was mixed with vermicompost in the ratio of 1:2; the size of the tub was selected 46 cm diameter, 32 cm height for culturing the *Solanum nigrum* plant saplings. The experimental setup was replicated two times.

D. Preparation of the liquid fertilizer

The room dried seaweed was cut into small pieces and powder made with mixer grinder. Then the powder material was taken for the preparation of seaweed Liquid Extract (SLE) by following the methodology described by Rama Rao, (1990). The algal sample was added with distilled water at the ratio of 1: 20 (w/v) and autoclaved at 121°C, 15 lbs/sq inch for 20 minutes. The hot extract was filtered through double layered cheese cloth and it was allowed to cool at 4°C.Then the filtrate was centrifuged at 5000 × g for 15 minutes. The supernatant was collected and considered as 100% of seaweed liquid extract. The extracts were stored in a refrigerator at 4ºc for later use. The seaweed extract were taken separately in container dilute the extract mixed with the distilled water.

The low concentration (20%) of the sea weed extract was sprayed by the foliar spray method, it enhance the absorption of the necessary elements by the plants. Six experimental setup were constructed in the grow bed and for the cultivation of Solanum nigrum plants. Solutions were sprayed twice month at 8:00 AM on a sunny day with a hand-held sprayer. Field data were collected in these experiments at one week interval followed by five weeks after transplanting including growth parameter of Solanum nigrum.

The physico-chemical parameter such as color, pH, calcium, and magnesium (Barrows and Simpson, 1962), EC of the sample was measured with the help of digital conduct meter. Sodium and potassium (Varian spectra-220AA atomic absorption spectrophotometer) of Aquaponic fish effluent water and seaweed extract were recorded. The nitrate, phosphorus, potassium, iron, zinc, and manganese content were analyzed and are described in Table 2. Finally, Field data's were collected in these experiments at 7days interval, including the growth parameter of Solanum nigrum plant. A meter rule was used to measure the height from ground level to the tip of the plant and the average was determined, seven days after the germination of seeds. The leaf area was calculated using the following formula (Otusanya et al., 2007).

LA=0.5*L*W, Where: LA=Leaf area,

The numbers of branches, moisture content and root and shoot dry weight was assessed by the plant samples (Somasundaram et al., 2008). Statistical analysis was performed using SPSS statistics 17.0 version. Statistical differences between treatments were tested using F test. Comparisons between variants were assessed using Post-hoc Duncan test for one way comparison. (ANOVA (α) =0.05).

Table 1. Experimental design used for cultivation of *Solanum nigrum* plant.

Experiment	Name of the Medium
Control - T1	Cocopeat + Borewell water
Exp. II -T2	Cocopeat + Borewell water + Turbinaria conoides
Exp. III - T3	Cocopeat+ Aquaponic water +Turbinaria conoides
Control - IV -T4	Soil + Borewell water
Exp. V- T5	Soil +Borewell water + Turbinaria conoides
Exp. VI - T6	Soil + Vermicompost + Turbinaria conoides

III. RESULTS AND DISCUSSION

A. Physical and Chemical Parameter

In this studies the physical parameters such as temperature, colour, electrical conductivity, odour, turbidity and total dissolved solids were measured (Table 2). The turbidity values of bore well and Aquaponic water and vermicompost were 0.1NTU, 1.52NTU respectively. Whereas, electrical conductivity were recorded as 1410µs/cm, 1750 µs/cm and 1230 µs/cm and total dissolved solids level were recorded as 230 mg/l, 493 mg/l and 1456 mg/l in turbidity values of bore well, Aquaponic water and vermicompost, respectively.

Values of chemical parameters of the samples were presented in the Table 3. The pH value in the bore well water Aquaponic water and the vermicompost were recorded as 7.55, 7.29 and 7.82. Biological oxygen demand 27ºc for 5 days level were observed as 3 mg/l5, 4mg/l and 110mg/l and chemical oxygen demand level were observed as 9.4mg/l, 37.5mg/l. 145 mg/l in borewell, Aquaponic water and vermicompost, respectively. The bicarbonate alkalinity values were recorded as 180mg/l, 122mg/l respectively in the aquaponic and vermicompost.

Temperature is an important parameter of the water body which regulates natural process with in the environment and governs physiological function in organism (Negi *et al*., 2008). Tilapia has a high tolerance of temperature, with the optimal growth at 27°C - 30°C (Colt, 2006). In this studies temperature was recorded within an optimum range for fish and plant cultivation. Srivatsava and Singh, (2014) reported that the similar temperature would be helpful to the more biological oxidation of organic matter and nitrifying bacteria can multiply with the optimum temperature (Wortman and Wheaton, 1991) for Nitrification process. Meske, (1985) has been observed in his experiment the optimum temperature of Aquaponic water would increase the tomato yield, similar results also observed in our experiment. Electrical conductivity most of the salts in the water are present in the ionic forms which are responsible for conduct electric current prakash and Somasekar, (2006); Wong *et al.*,(1997) reported that the gradual increase in EC was observed with increase in decomposition time and it might be the loss of weight of organic matter and release of different mineral salts in available forms (such as phosphate, ammonium and potassium). Jayakumar *et al.*, (2009a) observed increased EC in the vermicompost, the soluble salt level increases due to the mineralization activity and microorganisms in the organic matter. In our experiment more EC was observed in the Aquaponic water compare the vermicompost. Our work was supported by the studies of Rajasekar and Karmegam, (2009); Karthikeyan *et al.*, (2007). TDS is made up of inorganic salts, as well as a small amount of organic matter that included macro and micro nutrients. The total dissolved solids of organic and inorganic types are important parameter for plant growth. The results were indicated more TDS in vermicompost compare than the Aquaponic water. However, high concentration of suspended solid and dissolved solids adversely affect the plant growth (Mandal *et al*., 2010). Shelton and Popma, (2006) suggested that optimum level of pH enhance the plant and fish growth. In our study also pH was reported in the optimum level which was positive effect on fishes and plants growth. According to Princic *et al*., (1998) pH observed in the environment with high inputs such as ammonia from aquaculture wastewater, oxidation of this compound produces CO_2 and lowers the pH. The nitrifying bacteria growing on the root systems could have contributed to oxygen uptake (Sutton *et al.*, 2006). Oxygen distribution is important for the direct needs of many organisms and affects the solubility and availability of many nutrients and therefore it plays an important role in productivity. DO concentration under 2 mg/L, ammonia and nitrite oxidation by nitrifying bacteria becomes inefficient anymore (Masser *et al.*, 1999; Hargreaves, 2006). However, the present result was indicated above 6 mg/l of DO level in Aquaponic water which might influence higher plant growth in Aquaponic water than borewell water, respectively. Endut, (2010) reported that higher level of BOD would inhibit the fish and plant growth due to insufficient oxygen in the integrated Aquaponic system. Our results not similar to the above statement, nevertheless the BOD level was observed in Aquaponic water in lower range (5.4 mg/l) than vermicompost (110 mg/l), it may be a reason for higher growth rate while using Aquaponic water.

Parameter	Bore well (n=3)	Aquaponic (n=3)	Vermicompost (n=3)	F value	Sig.
Temperature	NA	27^a±0.58	28^a±1.53	0.375	0.57
Colour	Transparent	Pale yellow	Black	-	-
Electrical conductivity µS/cm	1410^b±20.82	1750^c ±20.82	1230^a±2.89	239.09	0
Odour	No perceptible (0)	Weak (2)	NP(0)	-	-
Turbidity (NTU)	0.1^a±0.04	1.52^b±.04	-	670.64	0
Total Dissolved Solids(TDS) (mg/l)	230^a±7.64	493^b±10.44	1456^c±7.00	5777.23	0

Table 2. Physical parameters of bore well, aquaponic and vermicompost system
Mean ± SE and ANOVA Significant at P<0.05 level

Table 3. Chemical parameters of bore well, aquaponic and vermicompost system

Parameter	Borewell (n=3)	Aquaponic water (n=3)	Vermicompost (n=3)	F Value	Significant
pH @ 25°c	7.55^{ab}±0.04	7.29^{a}±0.05	7.82^{c}±0.16	7.27	0.025
D.O	3.43±0.11	7.52±0.08	NA	2742.16	0.000
BOD	3±0.23	5.4±0.31	110 ±3.61	851.77	0.000
COD	9.4±0.17	37.5±0.83	145±1.45	5481.08	0.000
Total Alkalinity	180±5.1	122±5.3	NA	466.09	0.000

Mean ±SE and ANOVA Significant at P<0.05 level

B. Macro and Micro Nutrients

Macro and Micro nutrients of the sample values were presented in the Table 4. The results showed that NH_4 concentration level of the borewellwater, Aquaponic water and vermicompost were recorded as 0.02 mg/l, 0.33 mg/l and 28 mg/l, respectively. Nitrate level was recorded as not detectable, 35 mg/l and 1.49 mg/l, respectively. The value of phosphate were found as 0.44 mg/l. 10 mg/l and 17 mg/l. The potassium levels were recorded as 4.11 mg/l, 27 mg/l and 287 mg/l, respectively. Calcium and Magnesium level were recorded as 87 mg/l and 13 mg/l; 34 mg/l and 14.2 mg/l; 49 mg/l and18 mg/l, respectively. The Iron level was recorded as 0.3 mg/l, 0.2mg/l and 1.3 mg/l respectively. Chlorine and Zinc content were noted as 3.8mg/l and 0.02 mg/l; 7 mg/l and 0.08 mg/l; 1.9 mg/l and 0.18 mg/l respectively for the borewell water, Aquaponic water and vermicompost in the respective manner.

Table 4. Micro and Macro nutrients of borewell, Aquaponic and Vermicompost System

Parameter (mg/l)	Borewell (n=3)	Aquaponic water (n=3)	Vermicompost (n=3)	F value	Sig
NH_4+	0.02^{a}±0.01	0.33^{a}±0.02	28^{b} ±4.6	878.54	0
NO_3	ND	35^{c}±1.2	1.49^{b}±0.06	36.3	0
PO_4 3-	0.44^{a}±0.06	10^{b}±1.15	17^{c} ±2.0	38.85	0
Iron	0.3^{a}±0.06	0.2^{a}±0.1	0.13^{b} ±0.06	66.6	0
Mn	0.05^{a}±0.01	0.5^{b}±0.06	0.8^{c}±0.06	63.18	0
Mg	13^{a}±0.6	14.2^{a}±0.8	18^{b} ±1.33	7.33	0.03
Ca	87^{c}±2.1	34^{a}±0.6	49^{b} ±1.73	292.04	0
K	4.11^{a}±0.01	27^{b}±1.15	287^{c} ±2.08	13072.04	0
Cl^-	3.8^{b}±0.26	7.0^{c}±1.0	1.9 ^{a}±0.1	55.36	0
Zn	0.02^{a}±0.01	0.08^{b}±0.01	0.18^{c} ±0.01	117.6	0

Mean ± SE and ANOVA Significant at P<0.05 level

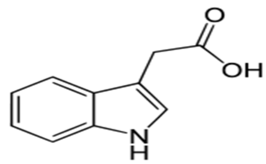
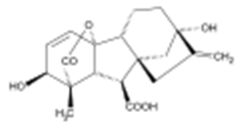
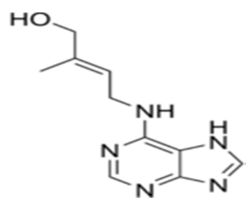
C. Nutrients and Growth Hormones present in the Seaweed

Macro and Micro nutrients and growth hormone level in the seaweed, *Turbinaria conoides* were presented in the (Table. 5 and 6). Nitrogen level in the seaweed was 4.34 mg/l. Phosphorus 127mg/l, Potassium 10.8mg/l, Calcium 96mg/l, and magnesium recorded as 58.3mg/l, (Fig. 4). The micro nutrients present in the *T. conoides* were recorded as Iron level was observed as 3.82mg/l. Manganese 0.05mg/l, Zinc 0.04mg/l, Boron 0.03 and copper 0.01mg/l. Growth hormone of the *T. conoides* was presented in the (Table 6). Auxin content was recorded as 55% followed by Gibberellin 49% and Cytokinin 24% which were essential for plant growth.

Table 5 Macro-micro nutrients in *Turbinaria conoides*

Parameter	Nutrients	Amount(mg/l)
Macro elements	Nitrogen	4.34
	Phosphorus	127
	Potassium	10.8
	Calcium	96
	Magnesium	58.3
Micro elements	Iron	3.82
	Manganese	0.05
	Zinc	0.04
	Copper	0.01
	Boron	0.03

Table 6. Growth hormone in *Turbinaria conoides*

Growth Hormones	Molecular structure	Hormone level	
		(μg/ml)	%
Auxin		104	55
Gibberellin		189	49
Cytokinin		93	24

D. Solanum Nigrum Seed Germination

The seed germination was observed in the *Solanum nigrum* plant (Fig.1) which was used in different substratum. In the Aquaponic water, seed was germinated at 2 days followed by the vermicompost 4 days and the seed germination was started in 10th day in soil. The result indicated that Aquaponic water seeds have higher growth compare the soil (T4).

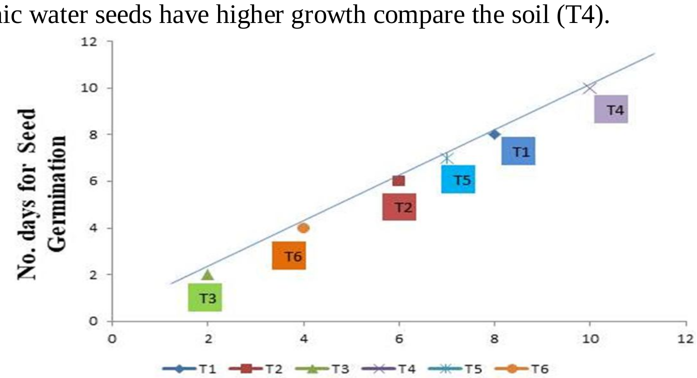


Figure 2. Seed germination on *Solanum nigrum*

E. Plant Height and Number of Leaves

Plant height and number of leaves there were significant differences ($p < 0.05$) among the treatment means on plant height from 8.97 cm (Table 7&8). Plant height and number of leaf increased with plant maturity. The height means for the duration of the trial were highest in T3 on the 7th week (90.25 cm) and compare the T6 (77.22) lowest in the control T1(46.23 cm) while the total number of leaves were ranged from 6.00 highest in T3 on the 7th week (349) and compare the T6 (253) and lowest in the control T1 (136). Gohari and Niyaki, (2010) reported that excess N and growth hormone (seaweed) increases plant height and shading of lower leaves leading to auxin production which eventually stops the plant's growth in the control. Millspaugh, (1974) reported *Solanum nigrum* plant height of between 30.48 and60.96 cm in his study and this was lower than the results of this present study. Edmonds and Chweya, (1997) recorded 70 cm as the maximum height of *Solanum nigrum* in their study; however this is lower than the maximum height recorded in the present experiment (90.33 cm). Nitrogen generally stimulates vegetative growth (Zhang *et al.*, 2010) meaning the formation of more buds and a subsequent increase in the number of leaves. From this study, it was conceivable that as the height increased due the uptake of N in its nitrate form, an increase in vegetative growth as indicated by the leaves became inevitable. In addition, the liquid fertilizer of seaweed by foliar spray in the Aquaponic water in the coco peat medium produced the highest leaf yield throughout the trail while vermicompost with liquid fertilizer of seaweed by foliar spray produced the average height throughout the trial.

Table 7. Observation of Plant height on Solanum nigrum plant.

Substratum	Plant age (Weeks after transplanting) (n=10)					
	0	3	4	5	6	7
T1	8.97^{a}±0.07	20.33^{a}±1.4	30.16^{a}±1.39	41.00^{a}±2.39	44.00^{a}±2.62	46.23^{a}±1.08
T2	8.97^{a}±0.07	21.10^{ab}±1.0	32.34^{b}±0.44	43.40^{ab}±1.71	46.46^{b}±.63	48.15^{ab}±2.6
T3	8.97^{a}±0.07	28.47^{d}±0.87	42.67^{d}±1.53	70.00^{e}±0.703	77.67^{e}±1.00	90.25^{e}±0.69
T4	8.97^{a}±0.07	21.29^{ab}±1.3	31.43^{ab}±1.3	44.00^{bc}±2.34	47.67^{b}±1.44	49.54^{b}±1.25
T5	8.97^{a}±0.07	22.32^{b}±0.83	32.66^{b}±1.36	46.33^{c}±1.11	49.64^{c}±0.90	52.10^{c}±0.46
T6	8.97^{a}±0.07	25.12^{c}±1.3	38.43^{c}±1.29	54.00^{d}±2.24	67.17^{d}±0.77	77.22^{d}±1.93
F Value	0	37.65	74.28	169.41	477.41	745.65
Significance	1	0	0	0	0	0

Mean ± SD and ANOVA Significant at P <0.05

Table 8. Observation of Leaf number on *Solanum nigrum* plant

Substratum	Plant age (Weeks after transplanting) (n=10)					
	0	3	4	5	6	7
T1	6.00^{a}±0.374	74^{a}±1.14	86^{a}±0.761	98^{a}±1.16	119^{a}±3.10	136^{a}±1.14
T2	6.00^{a}±0.374	79^{b}±1.18	89^{b}±0.79	110^{c}±2.35	131^{c}±1.71	152^{c}±1.58
T3	6.00^{a}±0.374	90^{d}±1.12	124^{d}±0.65	190^{f}±1.23	259^{f}±1.58	349^{f}±2.0
T4	6.00^{a}±0.374	72^{a}±1.58	86^{a}±1.22	103^{b}±1.58	126^{b}±2.74	148^{b}±2.74
T5	6.00^{a}±0.374	80^{b}±3.08	90^{b}±1.87	115^{d}±2.45	145^{d}±1.22	175^{d}±1.58
T6	6.00^{a}±0.374	85^{c}±1.58	109^{c}±3.74	172^{e}±0.58	223^{e}±4.62	253^{e}±0.71
F Value	.000	75.14	357.04	2396.07	2305.83	11363.29
Significant	0.0	0.0	0.0	0.0	0.0	0.0

Mean ± SD and ANOVA Significant at P <0.05

F. Leaf area

Leaf area increased until the 7th week in all the treatments and started to decrease. The treatment means were significantly different ($p < 0.05$) and ranged 2.44 cm^2 from the time of transplanting between 92.98 cm^2 in7th weeks at T3 (Table 9). The means for the trial period were highest in T3 (92.98 cm^2) and compare T6 (86.36 cm^2) lowest in the control (51.20 cm^2). Statistical analysis showed an interaction between plant age and the liquid fertilizer treatment on leaf area. Flowering commenced in the 4thweek and berries were first noted in the 5th week. Ripening was first observed in the 7th week, all the berries on all the plants were mature and ripe. Muthoni and Musyimi, (2009) reported that LA of 77.42 cm^2 in *Solanum scabrum* plants after 35 days (about 5 weeks). In the current study, after 7 weeks, the leaf area (LA) ranged between 53.55 and 92.98 cm^2. LA estimation is critical in plant nutrition, plant-soil-water relations, plant protection measures, plant competition, respiration, light reflectance as well as heat transfer, hence it is an important parameter in understanding water and nutrient use, photosynthesis, light interception and more importantly crop growth and yield potential (Mohsenin, 1986; Williams, 1987). In the present study application of liquid fertilizer of seaweed in the Aquaponic fish effluent water significantly increased LA as compared to other treatments up to the 7th week when the fruits started ripening. After we assume that nutrients such as N were at this time being remobilized and recycled and this led to a decline in LA. This study indicates that the plant went through all the growth phases successfully and Aquaponic water with seaweed liquid fertilizer was the best treatment.

Table 9. Observation of Leaf area on *Solanum nigrum* plant

Substratum	Plant age (Weeks after transplanting) (n=10)					
	0	3	4	5	6	7
T1	2.44^{a}±1.0	28.32^{a}±0.02	31.26^{a}±0.37	34.81^{a}±0.53	40.79^{a}±0.46	51.20^{a}±1.45
T2	2.44^{a}±1.0	32.64^{b}±2.40	37.43^{b}±1.04	43.22^{b}±1.66	53.21^{b}±1.53	62.76^{c}±1.31
T3	2.44^{a}±1.0	64.54^{d}±1.04	70.61^{d}±2.74	78.83^{d}±1.82	88.48^{d}±0.58	92.98^{e}±.48
T4	2.44^{a}±1.0	28.45^{a}±1.85	32.64^{a}±1.73	36.19^{a}±1.84	42.13^{a}±2.06	53.06^{a}±2.09
T5	2.44^{a}±1.0	34.43^{b}±2.04	37.62^{b}±2.61	45.86^{b}±3.80	54.91^{b}±1.60	56.85^{b}±3.04
T6	2.44^{a}±1.0	49.24^{c}±2.01	62.26^{c}±0.97	68.53^{c}±0.12	73.71^{c} ±0.09	86.36^{d}±0.23
F Value	0.001	202.38	260.14	244.57	657.3	327.6
Significant	0.0	0.0	0.0	0.0	0.0	0.0

Mean ± SD and ANOVA Significant at $P < 0.05$ level

G. Root and shoot Ratio

The root: shoot ratio decreased exponentially between the time of transplanting and the 3rd week and began to vary there after (Table 11). There were significant differences ($p < 0.05$). The means for the duration of the trial were highest at T3 (0.12) and compare the T6 (0.15) least at T2 (0.22) and T1 (0.26).

The results of the current study are comparable with those of Akubugwo *et al*., (2007) who reported moisture content of 84.70 %in *S. nigrum* leaves. Asibe y-Berko and Tayie, (1999) reported that the range between 79.6 and 80.4 % in *S. nigrum* also similar to the current study. Hussain *et al*., (2010) reported a range between 85.74 and 94.42 % in a *Solanum* species (92.60 %) and these results are not very different from the current study. Water constitutes about 80-95 % of the mass of a growing plant and thus plays a crucial role in the life of the plant. The high water content of *S. nigrum* leaves in this trial was not only a good indicator of the good quality and health status of the plant but also an indicator of its favorable nutritional status. All the treatments in this study generally indicated sufficient water in the leaves but coco peat with Aquaponic water by seaweed liquid fertilizer recorded the highest water content for the trial.

Table. 10 Estimation of Fresh Weight, Dry weight on Solanum nigrum plant

S.No	Substratum	Measurement (n=10)		
		Fresh Weight (gms)	Dry Weight(gms)	Moisture Content(gms)
1	T1	2^{a}±0.36	1.21^{e}±0.02	78.70^{a}±0.82
2	T2	2^{a}±0.36	1.19^{d}±0.001	81.40^{b}±0.27
3	T3	2^{a}±0.36	1.08^{a}±0.002	92.40^{e}±0.20
4	T4	2^{a}±0.36	1.19^{d}±0.003	81.10^{b}±0.61
5	T5	2^{a}±0.36	1.15^{c}±0.003	84.70^{c}±0.87
6	T6	2^{a}±0.36	1.12^{b}±0.003	88.10^{d}±0.60
F Value		0	86.135	206.868
Significance		1	0.0	0.0

Mean ± SE and ANOVA Significant at $P<0.05$ level.

H. Fresh Weight and Dry Weight

Fresh weight and dry weight of the each treatment means differed significantly ($p < 0.05$) and were consistently high throughout the experiment ranging between 75.16 and 92.40 % in the 7th and 3rd week respectively (Table 10). The means for the duration of the trial were highest in T3 (92.40) followed by T6 (88.10) and least in T1 (78.70).

Bvenura and Afolayan, (2013) revealed that the root: shoot ratio of S. nigrum was found between 4.1 and 32.9 that are not different from the current trial. The root: shoot ratio of some tomato cultivars and African nightshades increased in response to water stress conditions (Nahar and Gretzmacher, 2011).Reduced nutrient supply increases the root: shoot ratio thereby compensating for loss in root foraging capacities (Dixon, 2006). Furthermore, reduction in the root: shoot ratio is almost in response to more favorable growing conditions while increase on the other hand indicates growth of a plant in less favorable conditions (Harris, 1992).

Table 11. Ratio of Root and Shoot on Solanum nigrum plant

Substratum	Measurement n=10		
	Dry Root	Dry Shoot	Root:Shoot ratio
T1	3.1[a]±0.20	11.9[a]±0.26	0.26[a]±0.02
T2	3.3[ab]±0.20	14.9[c]±0.35	0.22[a]±0.017
T3	4.1[c]±0.26	32.9[f]±0.44	0.12[a]±0.02
T4	3.2[a]±0.36	13.2[b]±0.98	0.24[a]±0.09
T5	3.6[abc]±0.35	18.7[d]±0.40	0.19[a]±1.10
T6	3.8[bc]±0.26	24.6[e]±1.0	0.15[a]±0.046
F value	5.732	465.24	1.008
Significance	0.006	0	0.454

Mean ± SD and ANOVA Significant at $P < 0.05$ level

I. Chlorophyll Level

Chlorophyll a and b content of each treatment means were significantly different ($p < 0.05$) from T1to T6 (Table 12) and Chlorophyll a ranged between 24.10 mg/g at the time of transplanting and 30.85 mg/g in T3. The means for the duration of the chlorophyll a trial were highest at T3 (30.85 mg/g) followed by T6 (28.77mg/g) and least at T1 (24.20mg/g). Chlorophyll b ranged between 21.09 mg/g at the time of transplanting and 27.06 mg/g. The means for the duration of the trial were highest at T3 followed by T6 (28.77) and least at T1 Statistical analysis showed an interaction between plant age and the fertilizer treatment on chlorophyll content.

Masinde et al., (2009) reported higher values than the present study (between 40 and 70SPAD units in S. villosum). In a trial conducted on the field, reported that chlorophyll content was higher between 23.11 and 60.34 SPAD units in S. nigrum and this report is related to the present study (Bvenura and Afolayan, 2013). Therefore, an increase in values generally indicates an increase in chlorophyll content. Various authors agree that high chlorophyll values in plant cells are an indication of high N and therefore a good nutrient status of the plant.

Table 12. Analysis of Chlorophyll contents on Solanum nigrum

Chlorophyll contents	Types of Substratum (n=3)							
	T1	T2	T3	T4	T5	T6	F value	Sig.
Chlorophyll (a)	24.20[a]±1.6	25.02[ab]±1.3	30.85[d]±0.80	26.44[b]±0.9	27.08[bc]±1.6	28.77[cd]±0.52	12.44	0
Chlorophyll (b)	21.09[a]±1.0	23.22[b]±1.0	27.06[c]±0.16	24.15[b]±1.6	24.65[b]±1.3	25.19[bc]±0.57	10.69	0
Total chlorophyll	45.29[a]±0.8	48.24[b]±0.8	57.91[e]±0.38	50.27[c]±0.2	51.72[c]±1.3	53.96[d]±0.98	84.25	0

Mean ± SE and ANOVA Significant at $P<0.05$ level.

IV. CONCLUSION

This study is concluded that Aquaponic water along *Turbinaria conoides* with seaweed liquid fertilizer has different effects on the growth of *Solanum nigrum* cultivation indeed improves the yield and quality of the plant while physical growth is also enhanced. The lower concentration nutrients in the aquaponic water was acceptable to the plants *Solanum nigrum* because continuous supply of aquaponic water. Hence, this simple practice of application is an eco-friendly and sustainable food production system. Aquaponic fish water along with *Turbinaria conoides* seaweed liquid fertilizers to the plant is recommended to the growers for attaining better germination, growth, and yield. This soil-less culture system is modern farming practices in agriculture for food security. Aquaponic water and seaweed liquid fertilizers are bio-fertilizers.

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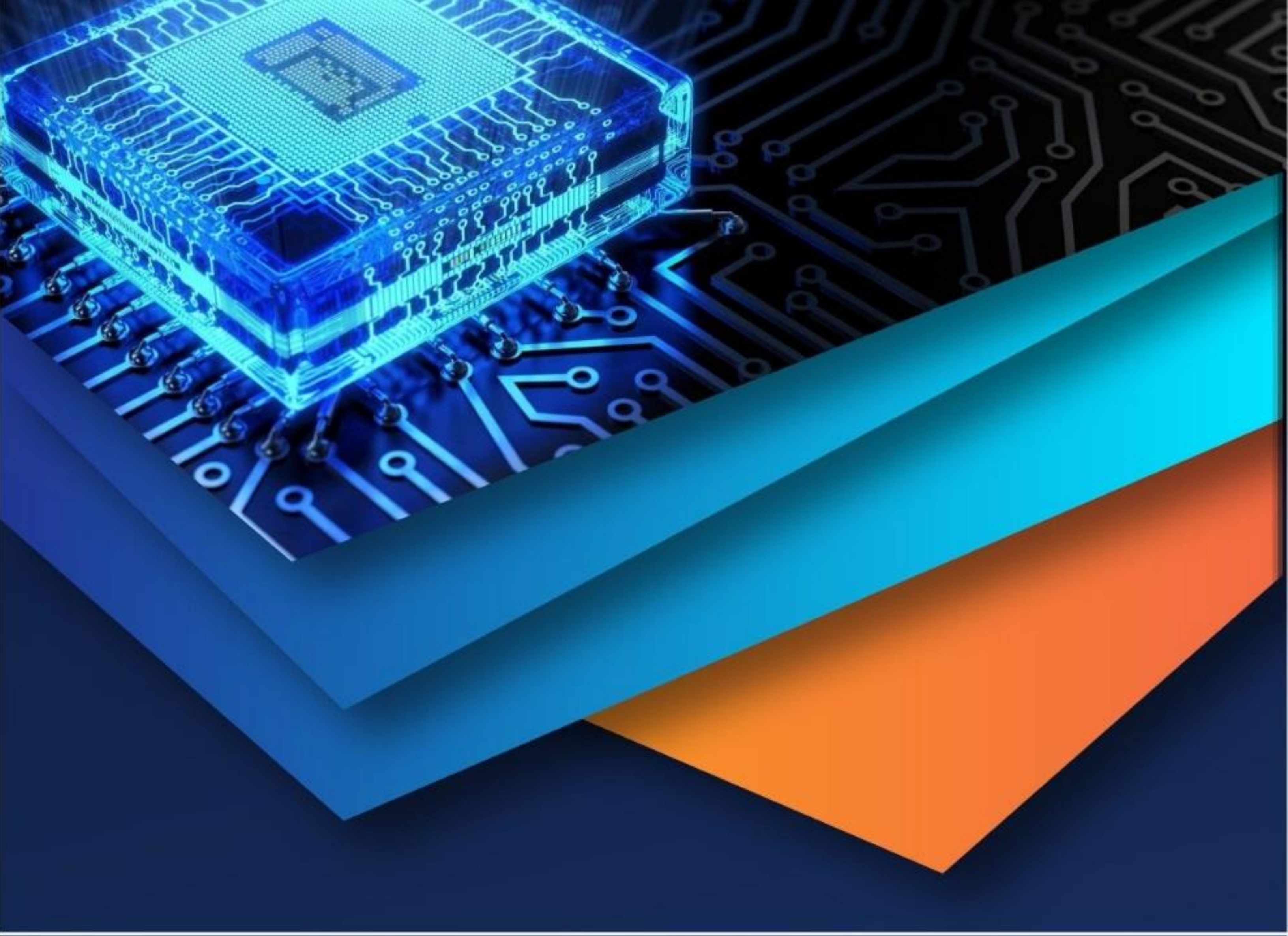

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