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Liza Akter Bethe
Department of Aquaculture, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh

MA Salam
Department of Aquaculture, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh

Umme Kaniz Fatema
Department of Aquaculture, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh

KM Shakil Rana
Department of Aquaculture, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh

Correspondence
KM Shakil Rana
Department of Aquaculture, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh

Effects of molasses and compost tea as foliar spray on water spinach (*Ipomoea aquatica*) in aquaponics system

Liza Akter Bethe, MA Salam, Umme Kaniz Fatema and KM Shakil Rana

Abstract
An experiment was conducted to evaluate the effect of foliar spray with molasses and compost tea on water spinach in aquaponics system. Nutrient Film Technique was employed for water spinach culture under three different treatments with molasses (T_1), compost tea (T_2) and no spray as control (T_3). Tilapia fingerlings, fed on a commercial diet, were reared in the aquaponics system. Waste water from the fish tank was re-circulated through the plant grow bed where nitrifying bacteria resided to convert toxic elements into plant available nutrients and supplied clean water to fish tank in return. 180 days trial revealed that T_2 yielded the highest production of 5.56 kg water spinach, followed by T_1 (4.73 kg) and T_3 (4.39 kg). The average productions of water spinach (2.17 kg/m^2/month) and tilapia (22.38 ton/ha/month) with an FCR of 2.33 suggest a prospective use of compost tea and molasses as foliar spray to produce organic vegetables**.**

Keywords: Aquaponics, foliar spray, compost tea, molasses, water spinach, tilapia

1. Introduction

Aquapoincs is a sustainable food production system that combines a traditional aquaculture (raising aquatic animals such as snails, fish, crayfish, or prawns in tanks) with hydroponics (cultivating plants without soil) in a symbiotic environment. The principal of aquaponics system is that the waste products of one biological system serve as nutrients to the other systems and the water is re-used through biological filtration. Because of the increased pressure on land use and intensification of aquaculture with high water demand, aquaponics has become the key method to sustain natural resources. In this system, water from the fish tank (containing unused feed, fish excreta etc.) is continuously pumped to the plant bed. This water is high in ammonia that is toxic for fish (Alabaster and Lioyd, 2013) [1]. The nitrifying bacteria that live on the surface of the plant bed convert ammonia into nitrates that can be used by the plants as nutrients. Therefore when tank water is pumped to the plant, toxic nitrogen is absorbed from the water through the plant roots as nutrients and provides clean water to the fish tank in return (Rakocy *et al.*, 1993) [2]. Water spinach (*Ipomoea aquatic*) is one of the suitable leafy vegetables for aquapincs system. It is a very popular vegetable in Bangladesh due to its availability at a low price, high nutrient content and medicinal values, especially for anemic and pregnant women who need iron in their diets **(**Shivananjappa *et al.*, 2012) [3]. However, this vegetable is often adulterated with various chemical fertilizers, insecticides and pesticides as grown in water that is mostly polluted. This ultimately threatens the public health. Regarding this an attempt was made to observe the effect of foliar spray with molasses and compost tea on water spinach to minimize health hazard in an organic way. For Fish culture, Tilapia (*Oreochromis nilotica*) was selected because of its better compatibility in aquaponics system and popularity in Bangladesh.

2 Materials and Methods

2.1 Experimental design

The experiment was carried out for 180 days in the Aquaponics Laboratory, Faculty of Fisheries, Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh. Nutrient Film Technique (NFT) was followed to observe the growth of water spinach in aquaponics system by using two different foliar sprays namely molasses and compost tea. The whole set up comprised a fish holding tank (750L) and three plastic pipes (20 ft long and 4 inch diameter), each with seven separate holes (3 inch diameter).

The holes were created at a same distance along each pipe to place porous plastic glasses in which water spinach were planted. Brick lets and gravels were used in the glasses as plant bed other than soil. The glasses were porous to allow the root of water spinach to come out and uptake the nutrients from the water passing through the pipes. The three different pipes were applied with three different treatments (T_1, T_2 and T_3) through 7 replications (R) each (Fig 1).

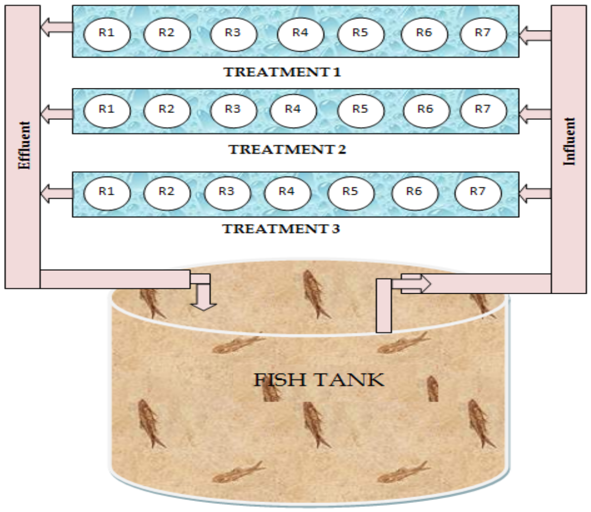

Fig 1: Experimental set up of the aquaponics system

Water spinach of the first pipe (from the top of the Fig 1) were treated with molasses under T_1, second pipe with compost tea under T_2, whereas third pipe was free from any spray and kept as control under T_3.

2.2 Rearing of fish in the tank

At first the plastic tank was disinfected with lime and bleach, bottom was prepared with a layer (6 inch) of small gravels; inlet and outlet of the tank for influent and effluent were made with plastic pipes and finally filled with underground water. Preparation of tank included cutting of upper end, washing, liming, plumbing pipes; setting gravels and fills up the tank with water. After disinfection with potassium permanganate solution (2 mg/l for 4 to 5 hours) and acclimatization for 30 minutes, eighty healthy monosex tilapia (*O. nilotica*) fingerlings (initial length and weight: 9.06±1.22cm and 17.27±6.50g respectively) were stocked in the tank. The fish were fed with commercial floating feed (size-1to3 mm) twice daily at a rate of 5% of fish body weight during 1st and 2nd month and then reduced to 3% in 3rd and 4th month, which finally became 2% in 5th and 6th month.

2.3 Planting water spinach saplings

Initially, water spinach seeds were germinated and planted in a plastic tray containing prepared soil. After 20 days, rooted water spinach were lifted up from the soil and then transferred to the plastic glasses. Fish tank waste water was used for watering the plants through a small PVC pipe (influent). This water when passed through the root systems of water spinach, was denitrified by the available nitrifying bacteria and collected to the fish tank through another small PVC pipe (effluent) as clean water for fish. Three pieces of foam were kept on the mouth of each plastic pipe for screening purpose. Foams were washed with clean water daily 2-3 times to remove the debris from it. Watering pipe was also cleaned regularly to prevent clogging and ensure maximum water supply. Water supply to the plant was stopped at night time. No chemical fertilizer or any other additive was used in spinach bed.

2.4 Preparation of foliar spray (molasses and compost tea)

To prepare the molasses spray, 1L of water and 1 table spoon of molasses were taken into a bottle and then mixed thoroughly. Then the solution was taken into the spray machine and sprayed over the water spinach leaf of treatment-1 (T_1). On the other hand, Compost tea is a solution of manure. For preparation, 1kg compost manure and 2 table spoons of molasses were mixed thoroughly with 10L of water in a container, then sieved and aerated for 24 hours. The prepared compost tea solution was then sprayed over the water spinach of the treatment-2 (T_2) with a spray machine. Foliar sprays (molasses and compost tea solution) were applied at- alternate week.

2.5 Sampling of Fish and plant

Fish of the tank and water spinach plant of the grow bed were sampled fortnightly whereas partial harvest of spinach was done monthly. Growth performance of the fish was evaluated by using standard mathematical procedures for analyzing total length and body weight data taken at each sampling. During each sampling, total length and weight of water spinach were taken by deducting the plastic glass weight and during each partial harvest weight of leaves and root were measured.

2.6 Physico-chemical parameters of the fish tank water

The physico-chemical parameters of tank water were measured to assess the quality of water before entering plant grow bed (influent) and after passing it (effluent). Dissolved oxygen (DO), Temperature and pH were measured every 15 days interval using test kits. Total nitrogen (Total-N), Electric conductivity (Ec), Carbonate (CO_3) Hydrogen carbonate (HCO_3), Potassium (K), Sulphur (S), Sodium (Na) and Calcium (Ca) were measured three times at one month interval during the experiment in the "Humboldt Soil Testing Laboratory" at Soil Science Department, Bangladesh Agricultural University (BAU), Mymensingh.

2.7 Data processing and analysis

Collected data were analyzed using "Microsoft Office Excel 2007" and "MSTAT" software to determine statistical significance.

3 Results and Discussions

3.1 Water Quality Parameters

The pH of fish tank water ranged from 7.5 to 8.1 over the study period with a mean of 7.73 (Fig 2). This suggests a favorable range of pH for both tilapia and nitrifying bacteria. Literature revealed that the pH range between 6.5 and 9 is the desirable range for tilapia culture (Swingle, 1968 and Huet, 1972) [4, 5], whereas the nitrifying bacteria growth is inhibited below a pH of 6.5 with an optimum pH of 7.8 depending on species and temperature (Tyson *et al.*, 2007) [6].

The average DO content in the fish tank was 2.38±1.0 ppm which was within the tolerance level of tilapia (Balarin and Hatton, 1979) [7]. The initial fall of DO two weeks after the beginning was might be due to the microbial and root respiration. The nitrifying bacteria growing on the root systems could have contributed to oxygen uptake (Sutton *et al.*, 2006) [8]. So, when re-circulated water was back to the fish tank, the DO level was decreased.

The water temperature recorded in the fish tank varied between 25.10 and 29.10° C with an average of 27.86 (Fig 2). This range of water temperature conforms to the suitable range of tilapia culture and nitrifying bacteria in aquaponics system (Wortman and Wheaton, 1991) [9].

3.2 Nutrient profiles of influent and effluent water in aquaponics system

The waste water that was supplied from the tank to the plant grow bed termed as influent whereas that denitrified water, after passing the grow bed (re-circulated), returned to the tank as effluent. The nutrient content such as phosphorus (P), potassium (K), sulphur (S), sodium (Na), hydrogen carbonate (HCO_3), carbonate (CO_3), total nitrogen (total-N) and electric conductivity (EC) of influent and effluent water was evaluated to determine the plant utilization in the aquaponics system (table 1).

The highest value of phosphorus (P) was 1.73±0.03 ppm that was found in the influent and 1.61±0.04 ppm in the effluent water in July when P removal was 6.9%. The highest P removal was 43% found in June. The minimum level of P in influent (0.16±0.01ppm) and effluent (0.06±0.001ppm) water was observed in May. Ghaly *et al.* (2005) [10] have examined the use of hydroponically grown barley for removal of phosphorus from aquaculture wastewater and reported P reduction ranged from 91.8% to 93.6%. Clarkson and Lane (1991) [11] evaluated the use of the nutrient film technique for P removal from the wastewater. During a 4-week period, the P concentration in the effluent was reduced from 4.4 to 0.3 mg/l using barley. Boyd (1998) [12] reported that tolerable limit of P in aquaponics system is in within 0.20-1.15 ppm that corresponds to the current study.

The maximum removal of total-N from the influent water was around 43% observed in May, whereas in June it was around 23%. However, data from July showed the minimum removal of total-N around 15%. In contrast, Ghaly and Snow (2008) [13] observed around 76% reduction of total-N in aquaponicss with barley. Endut *et al*. (2009) [14] have also found total-N removal of 64-78% using water spinach in aquaponics system. These variations are might be due to the difference in fish and plant species, environmental parameters as well as population of nitrifying bacteria harboring the re-circulatory system.

From the result of the experiment, it was found that K, S, Na and EC were decreased in the effluent throughout the culture period indicating the utilization of nutrients by the plants. During the experiment, HCO_3 was increased a little bit in May (Table 1). Possibly it was because of sampling or experimental error. However, the result justified that aquaponics system was capable of removing nutrients from the fish waste water and utilizing it for plant growth.

3.3 Plant growth and yield

The weight of leaves and roots of water spinach was recorded for all the three treatments, where T_1 was sprayed with molasses; T_2 with compost tea and T_3 with nothing as control. Although the leaves weight during partial harvesting from the three treatments were not significantly different over the period except in June, the highest leaves weight of 314.87± 132.52 g was harvested in T_2 on 10th July when T_1 and T_3 produced 291.81±126.40 g and 236.13±158.13 g leaves respectively (Fig 3). In contrast, the root weights significantly varied in different treatments over the period. Here, the highest roots weight of 114.59±32.86 g was also found in T_2 on 10th July with roots of 69.39±43.24 g and 103.92±29.89 g in T_1 and T_3 respectively. However, the observed average leaves weights were around 132.47 g, 156.37 g and 122.66 g as well as roots weights around 58.36 g, 75.94 g and 69.96 g in T_1, T_2, and T_3 respectively, where the highest values were found in T_2.

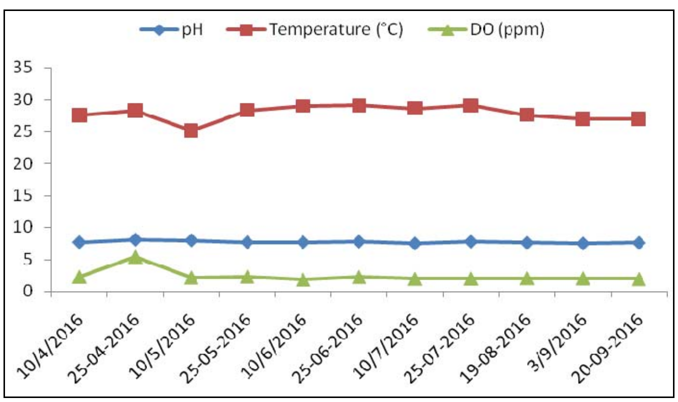

Fig 2: Water quality parameters of the fish tank

Table 1: Nutrient profile of influent and effluent water

Parameters	Influent			Effluent		
	May	June	July	May	June	July
P(ppm)	0.16±0.01	0.93±0.01	1.73±0.03	0.06 ±0.001	0.53±0.002	1.61±0.04
K (ppm)	6.12±0.28	5.27±0.01	5.75±0.14	6.02±0.42	0.84±0.04	4.64±0
S (ppm)	0.49±0.01	4.52±0.30	4.03±0.04	0.27±0.01	3.33±0.25	3.71±0.33
Na (ppm)	64.15±1.4	23.71±0.01	29.4±0	60±1.12	23.64±0.06	29.2±0.28
HCO_3 (ppm)	219.6±8.63	140.3±34.51	216.55±4.31	253.15±12.94	140.3±8.63	192.15±4.31
CO_3 (ppm)	0.0	34.5±2.12	0.0	0.0	22.5±2.12	0.0
Total-N (ppm)	4.9±0.99	22.15±0.35	29.4±1.98	2.8±0	17.05±0.35	25.2±0
EC (µs/cm)	662±2.83	567±1.41	574.5±3.54	666±5.66	489±1.41	549.5±0.71

Note: Values are given with ± standard deviation

The production of water spinach was better in T_2 that was sprayed with compost tea compared to other treatments. This is because, compost tea is a liquid that contains not only all the soluble nutrients extracted from the compost, but also all the beneficial species of bacteria, fungi, protozoa and nematodes (Diver, 2011) [15]. It improves plant growth by protecting the plant surfaces from harmful microbes. The beneficial microorganisms occupy the upper and lower sides and prevent pathogens from finding the leaves (Grubinger, 2005) [16]. It also assists in reducing the negative impact of chemical pesticides, herbicides and fertilizers as well as improves nutrient uptake by the root system (Diver, 2011) [15].

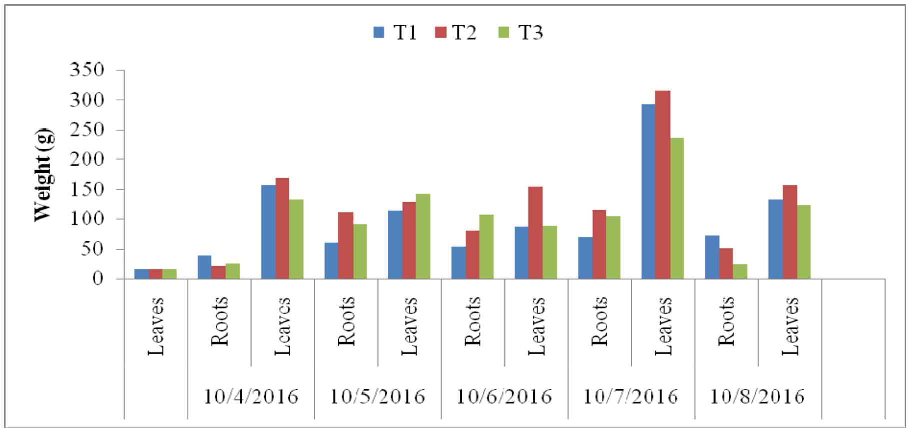

Fig 3: Leaves and roots weight of water spinach

However the total productions of water spinach throughout the study were 4.73 kg, 5.56 kg and 4.39 kg in T_1, T_2, and T_3 respectively, representing the better performance in T_2. The average water spinach production from the experimental aquaponics system was 2.17 kg/m^2/month. Endut *et al*. (2011) [17] have also produced an average of 2.14 kg/m^2/month of water spinach from aquaponics system.

Table 2: Weight (g) of leaves and roots of water spinach in different treatments on different dates

Date		T_1 (g)	T_2 (g)	T_3 (g)	Sig. L.
10-04-16	Leaves	15.32±5.85	15.97±11.73	15.53±9.24	ns
	Roots	38.63a±41.41	21.81c±13.16	24.96b±13.68	**
10-05-16	Leaves	156.21±44.37	168.06±29.78	132.15±26.13	ns
	Roots	59.22c±18.53	111.26a±38.88	89.75b±21.50	**
10-06-16	Leaves	113.45±30.59	128.77±61.04	141.48±36.56	ns
	Roots	52.95b±16.24	80.76ab±42.48	106.87a±24.09	*
10-07-16	Leaves	85.53b±33.11	154.16a±50.93	88.00b±29.87	**
	Roots	69.39±43.24	114.59±32.86	103.92±29.89	**
10-08-16	Leaves	291.81±126.40	314.87± 132.52	236.13±158.13	ns
	Roots	71.63±27.30	51.28±40.42	24.30±9.48	ns
Average	Leaves	132.47±102.76	156.37±106.93	122.66±80.62	
	Roots	58.36±13.39	75.94±39.69	69.96±41.89	

Note: Values are given with ± standard deviation. *, ** represent the values in the same rows are significantly different at 5% and 1% significant level respectively

3.4 Fish Growth and Production

In the present study with the aquaponics system, tilapia fingerlings were reared in the plastic tank for 180 days. The observed mean length gain was 11.77±2.49 cm and the mean weight gain was 170.38±78.7g at the time of final harvest (table 3). Midmore (2011) [18] has found that the mean weight gain of tilapia was 85.39±12.04 g after 180 days. Rearing fish in summer season at relatively higher temperature might be the reason behind this growth increment. The observed FCR (2.33) value was little bit higher than the expected FCR of 1.5-2.0 for tilapia culture (Watanabe *et al*., 2002) [19] which was might be due to increased temperature, feed loss and other experimental errors. Specific growth rate (% per day) was 0.98 g which is satisfactory. The survival rate was 85% because some fishes were died due to high water temperature and some were transferred to another tank. At the end of the experiment total production of tilapia was 11.59 kg from the 750 l tank at a rate of 22.38 ton/ha/month (134.30 ton/ha/180 days) which is nearly similar to Salam *et al*. (2014) [20] where tilapia production was 33.62 ton/ha/month (130 ton/ha/116 days) from the aquaponics system.

Table 3: Growth performances of tilapia

Growth performances	Value
Initial length (cm)	9.06±1.22
Final length (cm)	20.83±3.04
Length gain (cm)	11.77±2.49
% Length gain	231.29±28.10
Initial weight (g)	17.27±6.50
Final weight (g)	187.65±81.93
Weight gain (g)	170.38±78.7
% Weight gain	1161±526.84
Specific growth rate (% per day)	0.98
FCR	2.33
Survival rate (%)	85
Fish production per hectare	134.30 ton

4. Conclusion

The present study was accomplished with a view to find out a feasible way of producing hazard free organic vegetable (water spinach) using foliar spray of molasses and compost tea from aquaponics system. The main theme of aquaponics is the recirculation of water through the plant roots. From the influent and effluent water profile, it is clear that the nutrients of fish tank water, that would otherwise be toxic to fish, was absorbed by the roots of water spinach and then relatively clean water was returned to the fish tank. The study has revealed that compost tea gave better results than molasses spray in terms of spinach production while the tilapia production was satisfactory in the tank. There was no fertilizer or other chemicals used along the study, that assure a safe production of both fish and vegetables for human consumption. However, the 180 days trial provided an indication of prospective use of compost tea and molasses as foliar spray in the production of water spinach with a boosted up tilapia growth. Further research is needed for commercialization of compost tea and other organic foliar spray to sustain food safety.

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