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Influence of Aquaculture Effluent on Broccoli Yield and Quality

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Abstract: This experiment was conducted at Fish Nutrition Laboratory of the Faculty of Agriculture, Cairo University, Giza Governorate during 2010/2011and 2011/2012 seasons, to study the influence of Nile Tilapia(*Oreochromis niloticus* L.) aquaculture effluents as irrigation and fertilizer sources on broccoli yield and quality. Two types of tilapia aquaculture effluent production systems viz., Bio-floc and Intensive culture were used as irrigation water compared with mineral nutrient solution. Randomized Complete Block Design with three replications was used. Results showed that there were no significant differences between treatments in leaf area average and head dry matter percentage. Average head weight and harvest index were significantly affected by treatments on the two seasons, the highest head weight was recorded with the mineral nutrient solution. Meanwhile, no differences between Intensive culture and Bio-floc effluent in head weight average were detected. Hence, Intensive culture delayed ten days to harvest. The highest harvest index was recorded with the mineral nutrient solution followed by Bio-floc effluent. While, intensive culture had the lowest harvest index in the two seasons. It could be concluded that despite the superiority of the control (mineral nutrient solution) in head weight and harvest index. However, the most important finding is fish effluent treatments had less nitrogen accumulation in head and this healthier and reduces fertilizer costs.

Key words: Broccoli- aquaculture effluents- Bio-floc- Intensive culture- harvest index.

INTRODUCTION

Aquaculture is defined as the production of living organisms in water which encompasses both plants and animals in fresh or brackish water (Jasper, 1992).

Within the aquaculture industry, production units can be divided into open and closed (or water reuse) systems. Open systems take water in from one point and discharge it at another; hence they use the water once. Closed systems involve reusing the water and only adding new water to the system when water is lost. Closed culture units often have a series of filtration and processing components that help maintain water quality (Berghage, *et al*., 1999). One of the key issues of concern is the effluents produced in such systems. Each type of system differs in effluent quality based on production capacity, and effluents are a major concern, because they often are discharged in canals, creeks, rivers or seas. Currently, the industry is developing guidelines and technological innovations to tackle environmental issues by implementing practices to lessen pollution loads and to make use of aquaculture waste in an economical and beneficial way (EPA, 1980). One of the main products of any aquaculture system is the effluent, which tends to be high in nutrient and organic matter concentration. Discharge of nutrient rich effluents into natural water bodies can cause eutrophication or excessive plant growth and especially blooms of phytoplankton and other algae (Boyd and Tucker, 1998). Another concern is potential development of some blue-green algae species which are toxic and can have an adverse effect on the ecosystem in which aquaculture effluents are discharged Biological filtration (BF) is one of the most important methods by which water treatment takes place in many aquaculture units. A subset of BF uses plant filters to remove inorganic nutrients such as nitrates, nitrites, ammonia and phosphates. (Rennert, 1994). Integration of aquaculture with other animal and plant based systems has become a viable option to make use of the extra nutrients available from a production facility to reduce nutrient discharge (Wurts, 2000).

Hydroponics is a specialized method for horticulture production involving the growth of plants without soil. (Resh, 2004). Studies done by Wolverton (1987) showed that on a per acre equivalent basis potatoes, cabbage, tomatoes and lettuce production were 87%, 138%, 54% and 233%, respectively, more in hydroponic production than from normal field conditions. Aquaculture can be linked to an agricultural system in use the inorganic nutrients in effluents from aquaculture grow-out units to fertilize crop plants (Neori *et al*., 2004). Advantages of integration include but are not limited to: eliminating the cost and expertise involved in mixing traditional hydroponic nutrients, a source of inexpensive ‘organic’ or ‘natural’ fertilizer source, and integration reduces water consumption when compared to conventional aquaculture and plant production practices.

The low feed input to the fish tanks resulted in low nutrient concentrations in the water (Savidov, 2007). Hence, nitrogen, phosphorus, potassium and iron deficiencies were commonly seen in the crops.

The main usable components of fish effluent are calcium, magnesium, potassium, ammonia, nitrate, phosphate, sulfate, iron, manganese, zinc, copper, boron, and molybdenum (Al-Hafedh *et al*., 2008). Identifying

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concentrations of these nutrients present in effluent water as a function of the feed input, fish stocking density and fish species becomes a very useful tool in assessing the productivity of the water output of any aquaculture system. Aquaponic effluents contain many plant nutrients, but the levels of N and P in the effluent are of greatest concern. Fish feeds usually contain 0.5 to 0.8% phosphorus (Bergheim and Sivertsen, 1981).

The nutrients extracted from aquaculture effluent would reduce the synthetic nutrient requirement for plant fertilization (Resh, 2004). Although the nutrients from the fish system effluents are significantly lower than commercial grade nutrient solutions, supplementation with additional nutrients to achieve better results and lower overall production costs is possible (Rakocy *et al*., 2007). Nitrogen transfer from aquaculture to agriculture in integrated systems has been difficult to quantify, and understanding N utilization by crops has been poorly documented. Much work has been done in effort to understand N in integrated systems with varying results. Azevedo, *et al*. (1999) used labeled nitrogen 15N to determine N transfer from a fish system and its utilization by plants in an integrated system. Different treatments were amended at rates of 0%, 25%, 50% and 100% N. The results showed that the system efficiently recovered the N from the fish feed, but indicated that the effluent alone does not supply sufficient N for lettuce production.

(Boesch *et al*., 2001) reached that the water exchange rate was the largest and most decisive factor that affected the N levels in the effluent. Integrated aquaculture systems become a viable and attractive option that recycles nutrients, makes double use of water, and produces two products especially in arid area (Al-Hafedh *et al*., 2008).

Broccoli (*Brassica aleracea* L. var *italica* Plenk) is an amportant nutritious cole vegetable. It is high in vitamin A, ascorbic acid and is a good source of calcium, niacin and riboflavin (Decoteau, 2000). It is anticarcinogens in human foods and its beneficial effect on health is probably due to the immense variety of biologically active secondary metabolites which broccoli contains (Fahey and Stephonson, 1999; Johnson, 2000). Broccoli is a cool-season crucifer and a new crop for Egypt.

This study discus the influence of aquaculture effluent as irrigation and a fertilizer sources on broccoli yield and quality.

MATERIALS AND METHODS

This investigation was conducted at the Faculty of Agriculture Cairo University during two winter seasons of 2010/2011 and 2011/2012 .The objective of this study is to assess the discharge of two types of tilapia aquaculture effluent production systems viz., Bio-floc and intensive culture, used as irrigation water compared with mineral nutrient solution to evaluate the nutrient value of the effluent on broccoli yield and quality. The three treatments are different, in terms of water quality. Hence, the purpose of this study was to evaluate the possibility of using the effluent water from the fish tanks to grow broccoli. Broccoli was selected due to its short production cycle. In addition, broccoli is a high value crop. This experiment involved growing broccoli hybrid Centauro (Takii Co., Japan).Seeds were sown in the two seasons on 5th September in seedling trays . Forty days old transplants were planted in a complete randomized block (RCB) design with three replicates. Each experimental plot was 10 pots (40cm diameter) and pots were filled with sand, 80g compost, 5g super phosphate and 1g potassium sluphat in all treatments. Irrigation conducted three times weekly by one liter/pot in every irrigation cycle. Means of temperature at Giza governorate during Broccoli growth are listed in Table 1.

Three treatments were considered in the experiment:

Control treatment where broccoli plants were irrigated by water with addition of ammonium nitrate by 166mg/l in the first month increased to 332mg/l in the second month and reduced again to 166 mg/l in the third month. The other two treatments contained irrigation with effluent of two aquaculture systems namely Bio-floc and intensive culture without addition of mineral fertilization except in the second month where ammonium nitrate was added in rate of 166 mg/l. Plants were harvested after 90 days from transplanting.

The average chemical composition of the water types used in irrigation treatments during seasons of 2010/2011 and 2011/2012 are shown in Table 2.

Data were recorded on the following characters;

Vegetative characters:

Samples taken 40 days after transplanting and at harvest

- plant length from cotyledonary scare to leaves tip at 40 days only
- stem length from cotyledonary scare to shoot tip at harvest
- number of leaves more than 1-cm long (including scares)
- chlorophyll content (SPAD reading) in the most recent fully expanded leaf
- stem diameter
- leaf area average at harvest

Yield

A head was considered mature at the time before it started to lose compactness or just before buds started to break up.

Yield of top head

Head dry matter percent

Head chemical composition

Nitrogen, Phosphorus and Potassium percentage were determined according to the method described in AOAC (1990)

Ascrbic acid content was determined by titration method using 2,6 dichloro-phenol- indophenodye according to AOAC(1990)

Growth parameter

Harvest index (HI) = (EY/W) ×100 was measured at harvest.

Biological yield (W) = total plant dry matter at harvest.

Economic yield (EY) = yield of economic part of the plant.

Table 1: Means of temperature at Giza governorate during Broccoli growth.

Month	Temperature	
	Min.	Max.
September	21.8	33.1
October	19.2	29.9
November	14.9	25.0
December	10.7	20.5
January	9.1	18.8

Table 2: Average chemical compositions of water types used in irrigation treatment during seasons 2010/2011 and 2011/2012.

variable	Fresh water	Bio-floc effluent	Intensive culture effluent
Nitrite (µg/L)	Nd	0.12±0.029	0.11± 0.032
Nitrate (µg/L)	Nd	32.06 ± 11.04	30.01 ± 11.81
Total –N (mg/L)	Nd	3.68 ± 0.32	1.54 ± 0.26
Total-P (µg/L)	Nd	26.47 ± 8.84	0.25 ± 0.03
Total-K (µg/L)	Nd	35.28 ± 8.01	4.35 ± 0.97
EC(ds/m)	0.45	1.17 ± 0.013	0.51 ± 0.10
pH	7.75	8.08 ± 0.12	8.14 ± 0.07
Temperature(C°)	26.50	26.03 ± 0.95	25.09 ± 0.86

RESULTS AND DISSECTION

Data presented in Table 3 show that the lowest significant value of plant height, stem diameter, number of leaves per plant and chlorophyll content was obtained with Intensive culture effluent after forty days from transplanting in the first and second seasons.This is because the intensive culture effluent was low nutrient concentration.

Meanwhile, no significant differences between the mineral nutrient solution (control) and Bio-floc effluent in plant height, number of leaves and chlorophyll content.

(Boesch *et al*., (2001) reached that the water exchange rate was the largest and most decisive factor that affected the N levels in the effluent. Since the exchange rate is higher in intensive culture system.

Table 3: Influence of aquaculture effluent on plant height, stem diameter, number of leaves per plant and chlorophyll content of leaves (SPAD) of Broccoli after forty days from transplanting in 2010/2011and 2011/2012 seasons.

	2010/2011 Season				2011/2012 Season			
Treatments	plant height (cm)	stem diameter (mm)	no. of leaves /plant	chlorophyll content (SPAD)	plant height (cm)	stem diameter (mm)	no. of leaves /plant	chlorophyll content (SPAD)
Control	36.60a	12.88a	12.66a	74.06a	38.98a	12.39a	12.70a	74.74a
Intensive culture	28.73b	7.47c	10.20b	65.47b	31.76b	8.06b	10.86b	65.79b
Bioflok	36.13a	10.46b	11.93ab	72.78a	39.17a	11.08a	12.83a	74.7a

Values followed by a letter in common are not significantly different at the 0.05 level according to Duncan's multiple range test.

Data presented in Table 4 show that there were no significant differences between treatments in number of leaves and chlorophyll content in leaves at harvest in the first and second season. While, intensive culture effluent had the lowest significant value in stem diameter.

There were no significant differences between treatments in stem length in the first season .While; the mineral nutrient solution had the lowest stem length and no differences between Intensive culture and Bio-floc effluent in the second season. Rosenthal *et al*., (1993) compared the effect of fish effluent to mineral nutrient solution on fresh weight of lettuce and found no significant different between treatments. But, on dry basis, commercial hydroponic lettuce dry weight exceeded the aquaponics lettuce by of 27.1 %.

Table 4: Influence of aquaculture effluent on stem length, stem diameter, number of leaves per plant and chlorophyll content of leaves (SPAD) of Broccoli in 2010/2011and 2011/2012 seasons.

	2010/2011 Season				2011/2012 Season			
Treatments	stem length (cm)	stem diameter (mm)	no. of leaves /plant	chlorophyll content (SPAD)	stem length (cm)	stem diameter (mm)	no. of leaves /plant	chlorophyll content (SPAD)
Control	48.40a	17.70a	20.00a	68.88a	46.38b	17.28ab	19.50a	76.87a
Intensive culture	45.73a	15.07b	19.46a	76.44a	50.75a	15.07b	19.46a	79.36a
Bio-floc	49.46a	17.01a	18.86a	77.24a	51.40a	17.81a	18.23a	79.64a

Values followed by a letter in common are not significantly different at the 0.05 level according to Duncan's multiple range test.

Data presented in Table 5 show that there were no significant differences between the treatments in leaf area average and head dry matter percentage. Average head weight and harvest index were significantly affected by treatments on the two seasons, where the highest head weight recorded with the mineral nutrient solution. Meanwhile, no differences between Intensive culture and Bio-floc effluent in head weight average. Intensive culture delayed ten days to harvest.

The highest harvest index was recorded with the minerals nutrient solution followed by Bio-floc effluent, while, intensive culture had the lowest harvest index in the two seasons.

Azevedo, *et al.* (1999) concluded that 39.1% of the inorganic N was recovered from fish effluent when it was supplemented in a 1:1 ratio with N nutrient stock. The lowest N recovery of 15.7% was for fish effluente without N amendment. The reason for this is that plants can only utilize inorganic N and much of the nitrogen in straight fish culture effluent is in organic form and only 22.3% of the total N was in usable inorganic form. Although the inorganic N was almost completely removed from the effluent, it was not enough to provide a large yield of plant biomass.

Table 5: Influence of aquaculture effluent on leaf area average, head dry matter percentage, head weight average and harvest index of Broccoli in 2010/2011and 2011/2012 seasons.

	2010/2011 Season				2011/2012 Season			
Treatments	leaf area average (cm^2)	Head dry matter percentage (%)	average head weight (g)	Harvest index (g/plant)	leaf area average (cm^2)	Head dry matter percentage (%)	average head weight (g)	Harvest index (g/plant)
Control	113.80a	12.25a	284.66a	43.89a	126.50a	13.26a	260.28a	43.62a
Intensive culture	136.27a	13.57a	156.2b	29.31c	150.14a	13.24a	178.85b	27.73c
Bio-floc	139.98a	13.94a	201.76b	37.2b	147.89a	13.00a	209.60b	30.63b

Values followed by a letter in common are not significantly different at the 0.05 level according to Duncan's multiple range test.

Nitrogen concentration (Table6) was significantly affected by treatments the mineral nutrient solution (control) had the highest nitrogen concentration in the two seasons.

Bio-floc effluent had the lowest potassium and phosphorus concentrations in the first and second seasons. While, no differences between the mineral nutrient solution and Intensive culture in phosphorus concentration in the first season, and between Intensive culture and Bio-floc effluent in the second season. Palada *et al.* (1999) showed that fish effluent in integrated culture production produced low yield compared to mineral fertilizers, because, fish effluent contains low concentrations of N, P, and especially K in comparison to plant needs. Crops tend to take up N in some forms at faster rates than other forms. Crops like barley and lettuce take up ammonia N at faster rates than nitrate N, while another group of crops including Chinese cabbage, spinach and radish take up nitrate N at considerably higher rates than ammonia (Moritsugu *et al*., 1995).

Graber and Junge (2008) worked on measuring nutrient recovery from fish effluent after they planted three different crops: eggplant, tomatoes and cucumbers. The study showed that over a period of 105 days, the tomato crop was the most efficient nutrient removing plant with nutrient uptake rates similar to those of tomatoes grown in commercial hydroponic systems.

Vitamin C concentration was not affected by treatments in the first season. While, Bio-floc effluent had the lowest value, no differences between the mineral nutrient solution and intensive culture in the second season were found.

It could be concluded that despite the superiority of the control (minerals nutrient solution) in head weight and harvest index, followed by the treatment of Bio-floc. However, the most important finding is fish effluent treatments had less nitrogen accumulation in head and this healthier, reduces fertilizer costs and valuable nutrient resources and can be reused through the irrigation. In case prolong the harvest period can be used intensive culture effluent with Bio-floc effluent.

Table 6: Influence of aquaculture effluent on N, P, K and Vitamin C contents of Broccoli heads in 2010/2011and 2011/2012 seasons.

	2010/2011 Season				2011/2012 Season			
Treatments	N (%)	P (%)	K (%)	Vitamin C (mg/100mg dry weight)	N (%)	P (%)	K (%)	Vitamin C (mg/100mg dry weight)
Control	2.28a	2.27a	2.27a	1.92a	2.15a	1.75a	2.53a	1.67a
Intensive culture	.26b	1.74a	2.37a	1.74a	0.45b	1.12b	2.14b	1.80a
Bio-floc	.23b	.82b	1.55b	1.95a	0.24c	0.72b	1.83c	1.30b

Values followed by a letter in common are not significantly different at the 0.05 level according to Duncan's multiple range test.

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