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Integrated Production of Asian Catfish (*Heteropneustes Fossilis* Bloch) and Money Plant (*Epipremnum Aureum* Linden & André): A Promising Aquaponics System

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الإنتاج المتكامل لسمك القط الآسيوي (*Heteropneustes Fossilis* Bloch) وشجرة المال (*Epipremnum Aureum* Linden & André): كنظام زراعة مائية واعد

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ABSTRACT

The integrated production of fish with water-borne plants (hydroponics) is one of the most promising aquaculture (known as “aquaponics”) systems that is embraced around the world. Therefore, a study was conducted in triplicate for a period of forty days using 20L plastic containers to observe the growth performance of catfish (*Heteropneustes fossilis*) and money plants (*Epipremnum aureus*) in an aquaponics treatment system (hereafter “T_1”), and these results were compared with a monoculture of fish (T_2) and plants (T_3) in other treatments. Almost equal-sized and -aged juvenile catfish (total length: F1, 38 = 1.66, p = 0.20) were collected from a hatchery and were randomly assigned to T_1 and T_2, while similar-sized single-branched money plants (stem length: F1, 22 = 1.28, p = 0.27) were collected from the local market and were randomly planted into T_1 and T_3. Water quality parameters (e.g., temperature, salinity, pH, dissolved oxygen) were monitored regularly and did not show any significant variation or any deleterious effect on the growth of fish and plants. After the experimental period, the results showed that the final weight of T_1 catfish (aquaponics) was significantly higher than the T_2 treatment group (monoculture). In the case of the plants, total leaf number (p = 0.005), total leaf area (p = 0.0007) and total plant biomass (p = 0.011) of the T_1 group (aquaponics) were significantly higher than those of the T_3 group (monoculture). The results suggest that the integration of Asian stinging catfish with money plants provide a new avenue for sustainable fish food production along with hydroponics.

الملخص

يعد الإنتاج المتكامل للأسماك التي تحتوي على نباتات مائية (الزراعة المائية) أحد أكثر أنظمة الاستزراع المائي الواعدة (المعروفة باسم أكوابونكس "aquaponics") التي يتم احتضانها في جميع أنحاء العالم. لذلك ، أجريت دراسة على ثلاث مكررات لمدة أربعين يومًا باستخدام عبوات بلاستيكية 20 لتر لمراقبة أداء نمو سمك القط (*Heteropneustes fossilis*) ونبات المال (*Epipremnum aureus*) في نظام aquaponics (يشار إليه لاحقًا باسم "T_1") وقارنت هذه النتائج مع أسماك أحادية التربية (T_2) والنبات (T_3) في معاملة أخرى. تم جمع أحداث أسماك القط متساوية الحجم والعمر (الطول الكلي: F1، 38 = 1.66، p = 0.20) من مفرخ تم تخصيصه عشوائيًا إلى T_1 و T_2، في حين أن نباتات المال المفردة المتفرعة الحجم متماثلة (طول الساق: F1، 22 = تم جمع 1.28 ، p = 0.27) من السوق المحلية التي زرعت بشكل عشوائي في T_1 و T_3. تمت مراقبة معلمات جودة المياه (مثل درجة الحرارة ، الملوحة ، الأس الهيدروجيني ، الأكسجين المذاب ، وما إلى ذلك) بشكل منتظم والتي لم تظهر أي تباين كبير وكذلك أي تأثير ضار على نمو الأسماك والنباتات. بعد الفترة التجريبية، أظهرت النتائج أن الوزن النهائي لسمك القط في (aquaponics) T_1 كان أعلى بكثير من مجموعة المعاملة T_2 (زراعة أحادية). في حالة النبات كان إجمالي عدد الأوراق (p = 0.005)، إجمالي مساحة الورقة (p = 0.0007) واجمالي الكتلة الحيوية النباتية (p = 0.011) من معاملة (aquaponics) T_1 أعلى بكثير من مجموعة T_3 (الاستزراع الأحادي). تشير النتيجة إلى أن تكامل سمك القط الآسيوي مع نبات المال يوفر وسيلة جديدة لإنتاج أغذية الأسماك المستدامة إلى جانب الزراعة المائية.

1. Introduction

Aquaponics, a combination of fish and vegetable production in one integrated system, represents a significant advance for raising large amounts of food with limited land and water resources (Blidariu & Grozea, 2011). Such a production system can also be an approach utilized in areas where fish culture is not possible due to several anthropogenic activities and natural calamities including pollution, civilization, droughts, heavy rains, floods, poor farming techniques, land shrinkage and inclusion of salt water (Enduct et al., 2011; Fedoroff et al., 2010; McMurtry et al., 1997; Salam et al., 2013). In many third world countries where adequate protein sources and vegetables are not available for consumption due to the above reasons, the integration of fish and plants could be an alternative livelihood approach for the local communities.

The aquaponics system has so far been very popular in many developed countries because this system provides chemical-free healthy organic products, requires overall low water consumption, reduces production costs and ensures sustainable food production throughout the year (Martins et al., 2012). The effluent from intensive fish production systems contains high levels of nutrients that are normally discharged to the environment, contributing to pollution (Cao et al., 2007). In an aquaponics system, the waste nutrients are used to produce a valuable crop of vegetables (Graber & Junge, 2009). Removal of nutrients by vegetables purifies the water in a fish-rearing tank. In this system, there is no dirt to fertilize or weeds to pick. Ammonia produced from fish waste is converted into nitrates that nourish plants while the plants, in turn, filter the water that returns to the fish tank (Rakocy & Hargreaves, 1993; Rakocy et al., 2006; Roosta & Hamidpour, 2011).

A number of tropical and temperate fish species including sea bass, catfish, tilapia and perch have been identified as most suitable for fish—plant integrated culture systems around the world (reviewed by Mchunu et al., 2017). On the other hand, several types of leafy vegetables and plants including lettuce, water spinach, money plant, spinach, tomato, capsicum, cucumber, cabbage, carrots and mints are commonly practiced in this system (Effendi et al., 2017). Green plants, such as spinach, chives, lettuce, herbs, basil and watercress, have low to medium nutritional requirements and are well suited to aquaponics systems. Plants producing fruits, such as strawberries, tomatoes, cucumbers and peppers, have a higher nutritional demand and grow well even at high stocking densities. They are also well proven in aquaponics systems (Roosta & Afsharipoor, 2012).

Catfish (*Heteropneustes fossilis*), used in this study, is an air-breathing fish that can tolerate a wide range of environmental fluctuations (Saha & Ratha, 1998). It is not only recognized for its excellent taste but also highly sought after for its nutritional and medical benefits (Kohli & Goswami, 1989; Saha & Guha, 1939). Owing to its taste, medicinal values and live transportability, it fetches a high price in the local market (Acharya & Mohanty, 2014). In contrast, the money plant (*Epipremnum aureum*) also has nutritive value, and it requires less time and minimum space for

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growth and development. This plant is widely known in South East Asia and the Solomon Islands (Huxley et al., 1994), and has a reputation as a traditional anticancer preparation as well as a remedy for skin diseases (Meshram & Srivastava, 2014 and 2015). Phytochemical constituents in the money plant have potential applications for healing as well as for curing human diseases. It energizes the home by filtering air and increasing oxygen inflow (Das et al., 2015). The purpose of this study was to observe the growth of Asian stinging catfish (*H. fossilis*) and money plants (*E. aureum*) reared together in an aquaponic system and to compare their results with fish and plants reared separately without an aquaponics system. This study also evaluated the water quality parameters under various experimental conditions.

2. Materials and Methods

2.1. Fish Collection and Maintenance:

Approximately fifty (50) juvenile catfish (*H. fossilis*) of the same age and almost equal size (weight: 2.8 to 2.9 g, $F_{1,38}$= 1.04, p = 0.32 and total length: 7.6 to 7.8 cm, $F_{1,38}$ = 1.66, p = 0.20) were collected from the Jessore Fish Hatchery, Jessore, Bangladesh and transported in oxygenated containers to the fish rearing facilities of Fisheries and Marine Resource Technology Discipline (FMRT), Khulna University, Bangladesh. The fish were then stocked in a large round plastic tank (20L) and fed (until satiation) commercial floating feed (Mega Feed Ltd.) for two days to adapt to the new systems. All the experiments were conducted at room temperature (25±2° C).

2.2. Plant collection and Maintenance:

Twenty-four (24) money plants (*E. aureum*) of almost the same size (stem length: $F_{1,22}$ = 1.28, *p* = 0.27) were collected from the Khulna New Market Nursery, Khulna, Bangladesh. The plants were then transported to the fish rearing facilities of FMRT Discipline and placed in a hydroponic bed, which was made up with cork sheet.

2.3. Experimental Procedure:

This study was designed with three experimental conditions in triplicate for forty days. In treatment 1 (T_1), tanks were stocked with fish and plants, while treatment 2 (T_2) and treatment 3 (T_3) tanks were stocked with only fish and only plants, respectively. The stocking density of fish and plants in each tank was 10 and 6, respectively. A twenty-liter (20L) plastic tank equipped with continuous aeration was used in this experiment. Tanks in T_2 were covered with nets to avoid fish escaping. Experimental fish were fed with commercial floating feeds (Mega Feed Ltd.) twice a day between 10 am and 10 pm until satiation. Uneaten feed was removed every day after 30 minutes of feeding. Approximately 20% of water was exchanged every other day. The plastic tanks were kept close to the windows to receive sufficient light for the plants.

2.4. Determination of Water Quality Parameters:

The water quality parameters were assessed in the Water Chemistry Research Laboratory of FMRT Discipline. Temperature, pH and dissolved oxygen (DO) were determined by a Celsius thermometer, bench top digital pH meter (Digital pH meter DPH-2, ATAGO) and Winkler methods, respectively, whilst alkalinity, hardness and ammonia (NH_3) were measured by standard methods (APHA, 2008).

2.5. Determination of Fish and Plant Growth:

Fish growth (weight and length) and plant growth (leaf number, root length, stem length, leaf area and plant biomass) were compared in the initial day of stocking and final day of harvesting. Fish weight was measured using a digital weight balance, while fish length was determined by ImageJ (v1.50) software. At first, the fish was placed on graph paper and the photographs were taken by a digital camera. All the raw images were imported into ImageJ (v1.50) software for the measurement of total length (in cm), which was defined as from the fish snout to the tip of the longer lobe of the caudal fin (Fig. 1). Similar software was also used to carefully measure the root length (the distance in cm from stem to soil strip, Fig. 2), the stem length (the distance in cm from root to leaf, Fig. 3) and the mean leaf area (in cm^2, Fig. 4) of the money plants.

Fig. 1. Measurement of fish length

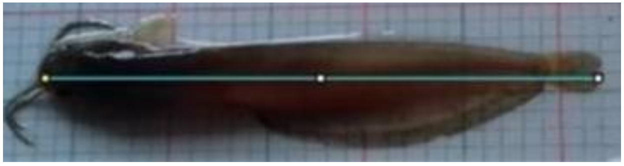
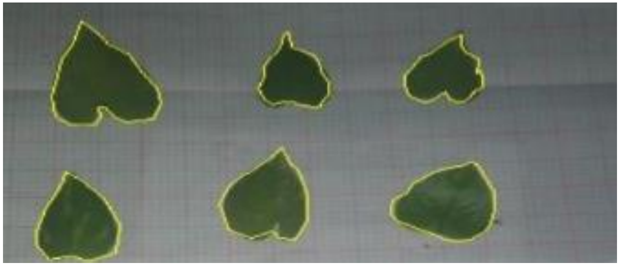


Fig. 2. Measurement of plant root length

Fig. 3. Measurement of plant stem length

Fig. 4. Measurement of mean leaf area



2.6. Statistical Analyses:

All the analyses were performed using "RStudio" version 1.0.143 (RStudio Team, 2016). The descriptive statistics (means, SD, SE, etc.) were calculated using the "psych" package (Revelle, 2017), and the Shapiro–Wilk test of normality and the Levene's test for homogeneity of variance were applied with the "car" package (Fox & Weisberg, 2011).

The physiochemical parameters of water samples were analyzed after the normality and homogeneity tests. Next, the one-way analysis of variance (ANOVA) model was applied using the "car" package (Fox & Weisberg, 2011) for the parameters that followed the assumptions, while the Welch test was performed for those which were not normally distributed and heteroscedastic using the "one-way tests" package (Dag et al., 2018).

The growth parameters of fish (e.g., total length and weight) and plants (e.g., leaf number, leaf area, stem length, root length and total biomass) were tested to check their normal distribution and then appropriate transformations were applied to yield normal distributions for non-normal distributed traits. Then, the ANOVA model was performed to explore the variation in growth parameters of fish and plants between the treatment groups. All plots were prepared using the "ggplot2" package (Wickham, 2009).

3. Results

The overall growth performance of fish and plants under various experimental conditions is shown in Table 1. The statistical analyses revealed some significant effects of treatments on some phenotypic traits of the stinging catfish and money plants, which are also mentioned in Table 1.

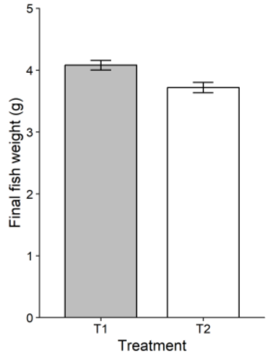
Table 1: Fish and plant growth in response to various treatments at the end of forty-day experimental period.

Phenotypic traits	Treatments (Mean ± SE)			F	p
	T_1	T_2	T_3		
Fish growth parameters					
Initial total length (cm)	7.83±0.09	7.62±0.13	-	1.66	0.205
Final total length (cm)	8.91±0.17	8.66±0.15	-	1.01	0.321
Total length gained (cm)	1.08±0.15	1.03±0.15	-	0.11	0.738
Initial weight (g)	2.94±0.07	2.84±0.08	-	1.036	0.315
Final weight (g)	4.08±0.08	3.72±0.08	-	10.43	***0.003***
Weight gained (g)	1.14±0.11	0.88±0.09	-	3.26	0.079
Plant growth parameters					
Initial total leaf number	6.75±0.39	-	6.33±0.50	0.433	0.517
Final total leaf number	11.42±0.77	-	8.58±0.50	9.475	***0.005***
Total leaf no gained	4.67±0.64	-	2.25±0.37	9.30	***0.006***
Initial stem length (cm)	8.08±0.73	-	6.67±1.02	1.276	0.271
Final stem length (cm)	9.68±0.89	-	7.50±0.97	2.777	0.11
Stem length gained (cm)	1.6±0.21	-	0.83±0.07	12.43	***0.002***
Initial root length (cm)	7.33±0.47	-	6.83±0.51	0.529	0.475
Final root length (cm)	8.98±0.52	-	8.01±0.53	1.697	0.206
Root length gained (cm)	1.65±0.23	-	1.18±0.11	3.52	***0.001***
Final mean leaf area (cm2)	6.42±0.42	-	4.57±0.22	15.48	***0.001***
Initial plant total biomass (g)	6.99±0.45	-	6.15±0.41	1.93	0.178
Final plant total biomass (g)	9.55±0.6	-	7.42±0.49	7.62	***0.011***
Total biomass gained (g)	2.56±0.24	-	1.21±0.13	21.9	***0.001***

Significant p-values are marked in bold and italic fonts. T_1 – Catfish with money plant; T_2 – Only catfish and T_3 – Only money plant.

At the end of the study, fish weight varied significantly whereby fish reared with plants (T_1) had a higher weight ($F_{1,38}$ = 10.43, p = 0.003) than the group reared without plants (T_2) (Fig.5). However, no significant variation was observed between the treatment groups in terms of fish length (Table 1).

Fig 5. Variation in fish weight (mean ± SE) between the two treatment groups



The results revealed that money plants in the T_1 treatment group (aquaponics) had a significantly higher number of leaves ($F_{1,22}$ = 9.48, p = 0.005), larger leaf areas ($F_{1,22}$ = 15.48, p = 0.0007) and a higher total biomass ($F_{1,22}$ = 7.62, p = 0.011) than the plants in the T_3 treatment group (monoculture) (Table 1 and Figs. 6–8). The study also revealed no significant variation in stem length and root length (Table 1).

Fig 6. Variation in total leaf number (mean ± SE) between the two treatment groups

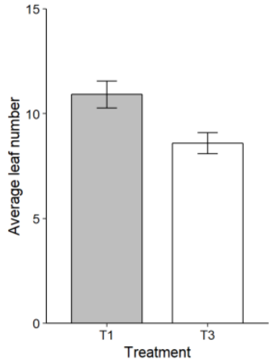


Fig 7. Variation in mean leaf area (mean ± SE) between the two treatment groups

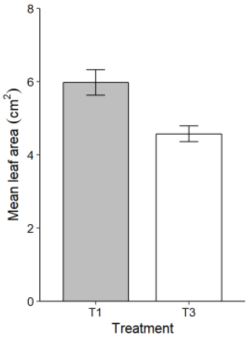
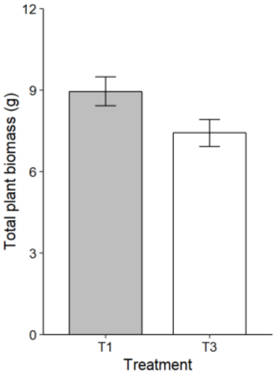


Fig 8. Variation in total biomass (mean ± SE) between the two treatment groups



The overall water quality parameters of different treatments are summarized in Table 2. The study found no variation between the treatment groups in terms of temperature, pH, alkalinity, water hardness and ammonia, whereas a significant difference was revealed in DO level ($F_{1,27}$ = 5.69, p = 0.009). The subsequent post-hoc test for a pairwise comparison revealed that the T_3 group had significantly reduced the level of DO compared with T_1 (p = 0.04) and T_2 (p = 0.02), while no significant variation was observed between the T_1 and T_2 groups (p = 0.81).

Table 2: The results of exploring the water quality parameters among different treatments

Parameters	Treatment (Mean ± SE)				F	p
	T_1	T_2	T_3	Models		
Temperature (°C)	28.06±0.57	28.00±0.52	27.75±0.38	ANOVA	0.11	0.899
pH	8.26±0.16	8.37±0.12	8.51±0.08	ANOVA	0.97	0.385
DO (mg/L)	7.44±0.39	7.56±0.34	6.44±0.18	Welch test	5.69	***0.009***
Alkalinity (mg/L)	443.7±18.2	450.0±14.4	443.8±12.0	ANOVA	0.06	0.946
Hardness (mg/L)	90.00±3.87	90.00±3.42	88.12±2.77	ANOVA	0.12	0.889
Ammonia (mg/L)	0.01±0.00	0.01±0.00	0.01±0.00	ANOVA	0.18	0.8332

Significant p-values are marked in bold and italic fonts. T_1 – Catfish with money plant; T_2 – Only catfish and T_3 – Only money plant.

4. Discussion

Aquaponics technology promises to provide nutritious chemical-free organic products to local communities by maximum utilization of land and spaces. It is a sustainable and efficient food production technology that can produce a high yield of fruits, vegetables and fish in any conditions, using no soil and less water than the usual requirements. This study evaluated growth performances of Asian stinging catfish and money plants under three experimental conditions. This integrated culture in an aquaponics system proved that money plants had no negative impact on the growth and survival of catfish. We did not notice any dead fish or money plants in any of the treatments throughout the study period.

Asian stinging catfish growth, in terms of length and weight, was found to be higher in the integration of fish and plants than in the fish culture alone, similar to reports in several fish species reared with different plant species (Effendi et al., 2017; Hussain et al., 2014; Mamat et al., 2016). In an aquaponics system (fish and money plant), fish length and weight increased by approximately 13.8% and 39%, while, without plants, fish length and weight increased by approximately 13.5% and 31% from the initial stocking size.

Survival rates of stinging catfish and money plants remained unchanged (100%) in all treatments during forty days of rearing. High survival rates were also observed by Hussain et al. (2014), Shete et al. (2013) and Effendi et al. (2017) for Koi carp, goldfish and Nile tilapia, respectively. On the contrary, lower survival rates (0 to 65%) under an aquaponics system were observed by Mariscal-Lagarda et al. (2012) and Kuhn et al. (2010) for white shrimp species, and they reported such a low level of survivability due to an elevated concentration of nitrate in the system. The water quality parameters throughout the present experiment were within the acceptable level (see below), which might be the reason for the high survival rate of catfish. In recirculating aquaponics systems, water becomes polluted with fish effluent that increases the possibility of ammonia concentration. This concentrated ammonia is always lethal to aquatic animals. In this study, we exchanged approximately 20% of water twice a day in addition to the removal of feces and uneaten feed that might control ammonia in fish tanks. Nevertheless, additional research is required to confirm whether aquaponics without a water recirculation system improves the aquaculture production on a mass scale. Water exchange in most commercial operations is a common practice for the elimination of nitrogenous substances (Endut et al., 2011).

The present study shows substantial variations of plant growth in different treatments. The total number of money plant leaves increased by approximately 69% when money plants were cultured with catfish, but the total number of leaves only increased by approximately 36% when plants were cultured without fish. Stem length and root length of money plants also increased by approximately 20% and 23%, respectively, when there was an integration of fish and plants. This was in contrast to conducting with only plants (12% for stem length and 17% for root length). Our results are inconsistent with the findings of Effendi et al. (2017) and Hussain et al. (2014), who used romaine lettuce and spinach, respectively. In general, plants develop significantly with dissolved nutrients that are directly excreted from fish waste or caused by the microbial breakdown of fish waste in an aquaponics system. The roots of plants in water not only absorb nutrients but also provide a shelter for the attachment of beneficial microbes (Endut et al., 2010; Hu et al., 2015; Roe & Midmore, 2008).

In this study, initial leaf area was not measured due to its very small size. However, between the treatments (with and without aquaponics) leaf size varied significantly at the end of the experiment. When the fish were integrated with money plants, the mean leaf area of the plant increased by approximately 40% compared to the only plant cultivation. The overall plant biomass was also higher in the integrated system. Working with aquaponics systems (fish with tomato, cucumber and lettuce), Savidov (2005) and Lennard and Leonard (2006) reported a better growth pattern compared to traditional systems.

Water quality parameters have a direct influence on fish health and overall fish growth. This study demonstrated that water quality parameters (DO, pH, temperature, alkalinity, hardness, ammonia) in aquaponics systems were within the acceptable level of fish culture in particular catfish species. There were no major changes in physicochemical parameters among treatments except DO, ranging between 5 and 10 mg/L. DO is one of the most important growth regulating factors for aquatic animals (Pillay & Kutty, 2005). In general, DO values between 4 and 10 mg/L are recommended for normal physiological activities of fish at 22–32°C (Filep et al., 2016; Yildiz et al., 2017). In this study, we observed a lower value of DO in treatment $T_{3,}$ and this might be due to the absence of an external aerator, as no fish were stocked in this treatment. Another reason could be the passive uptake of oxygen by the money plant. However, this hypothesis needs to be confirmed by further research.

5. Conclusion

This study demonstrated that aquaponics is an effective way to rear plants and fish in one system. The overall growth of catfish and money plants in the aquaponics treatment group was significantly higher than in the fish only group or the plant treatment group. Water quality parameters obtained in this study had no adverse effect on the growth and survival of catfish and money plants. Rearing of catfish appeared to positively co-exist with money plants. Effectiveness of other plant species with this valued catfish species deserves further investigation.

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