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Production of organic grass carp (*Ctenopharyngodon idella*) and GIFT tilapia (*Oreochromis niloticus*) using napier grass, *Pennisetum purpureum*

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Abstract

This study was conducted to examine the growth and production of grass carp and tilapia cultured organically using napier grass in Bangabanbhu Sheikh Mujibur Rahman Agricultural University, Bangladesh from March-June, 2013. Three stocking ratios were tested: grass carp at 0.6 fish/m^2 with GIFT tilapia at 0.3 fish/m^2 (T_1), grass carp at 0.6 fish/m^2 with GIFT tilapia at 0.6 fish/m^2 (T_2), grass carp at 0.6 fish/m^2 with GIFT tilapia at 0.9 fish/m^2 (T_3) and grass carp only at 0.6 fish/m^2 as control (T_4). Chopped fresh napier grass leaf was the sole nutrient input and provided twice daily. The water quality parameters were within suitable ranges for fish culture. Grass carp attained a daily growth increment ranging from 2.80-3.73 g/day and GIFT tilapia from 1.30-1.86 g/day. The combined yields was significantly higher ($P<0.05$) in stocking ratio of 1:1 (2.72 t/ha/90 days) compared to other stocking ratios. The result indicates on the basis of benefit-cost-ratio that the farmer's income will be around double or more in the combined production of organic grass carp and tilapia with stocking ratio of 1:1 than the other stocking ratios. The density of grass carp should be further studied.

Keywords: Organic aquaculture, grass carp, GIFT tilapia, napier grass, growth performance, fish production

INTRODUCTION

Aquaculture is the production of fish under controlled conditions. The major problems with industrial aquaculture are the use of chemical, antibiotics and farmed fish feed polluting surrounding aquatic environment both fresh and marine. Therefore, organic aquaculture has been gaining considerable importance in recent years as organic fish farming system virtually prohibit utilization of synthetic chemicals in fish production (Majhi 2006). Many farmers have started shifting from traditional method to organic cultivation for producing safe foodstuff. Organic farming favours lower input costs, conserve nonrenewable resources, high value markets of the organic fish product and thereby increase farm income (Majhi 2006).

Grass carp (*Ctenopharyngodon idella*), an herbivorous species, is a commonly cultured species in many parts of the world (Pandit *et al.* 2004). In Bangladesh, Grass carp has been introduced in 1966 from Hong Kong for controlling aquatic weed (Talwar and Jhingran 2001, Rahman 2005) and occasionally used in polyculture system. However, grass carp consume low value vegetative waste and increase natural food production in the pond by nutrient recycling and fecal production (Yang *et al.* 1990, Li and Mathias 1994). As grass carp are known to feed on a wide variety of plants, the quantity and quality of natural food production derived from recycling of grass carp wastes depend largely on the type and input of forage provided.

Green grass has an important role in feeding grass carp (Shrestha and Yadav 1998) in addition to aquatic vegetation such as *Azolla* sp., *Lemna* sp., etc. (Majhi *et al.* 2006, Ferdoushi *et al.* 2008). Napier grass once sown on pond banks, is a perennial tropical grass (Edwards 1982) accepted by grass carp (Venkatesh and Shetty 1978, Shrestha 1999). In addition, a major portion of plant biomass consumed by grass carp returns to the pond as organic manure stimulates plankton production for other planktivorous fish in the same pond (Woynarovich 1975) and tilapia is an excellent candidate to utilize these natural foods derived from plants fed to grass carp (Pandit *et al*. 2004).

In the polyculture of grass carp and tilapia, large grass carp can prey to some extent on tilapia fry spawned in the pond (Spataru and Hepher 1977). However, the grass carp is not predacious on small fingerling fishes of Nile tilapia (Pandit *et al*. 2004). Pandit *et al.* (2004) also found that growth and yields of Nile tilapia in polyculture with grass carp were lower due to recruitment of Nile tilapia fry through prolific breeding and resultant food competition diminishes growth and production of tilapia. Fast growth monosex GIFT tilapia (male) can be used to resolve this constrain through avoiding recruitment of new tilapia population and food competition which is one important purpose of this study.

Moreover the use of commercially manufactured pelleted feeds predominates in entrepreneurial GIFT tilapia culture in Bangladesh (Belton *et al*. 2011). However, the major constraints for small-scale, resource-poor farmers are fish feeds and chemical fertilizers, which are expensive and unavailable (Shrestha and Yadav 1998, Shrestha 1999, Belton *et al*. 2011). Livestock manure (cow dung) has traditionally been used by these farmers for aquaculture. Recently, the availability of this livestock manure has been decreased due to decreasing the cattle number owing to increasing intensity of mechanical ploughing of land instead of cattle ploughing. Therefore, easily available or easily grown plant material is a prime need to solve the problems of these fish farmers as well as to produce organic fish by maintaining ecologically friendly environment. The purpose of this study was to evaluate the growth performance and production of grass carp and GIFT tilapia cultured organically using napier grass.

METHODOLOGY

This experiment was conducted in the field complex ponds of Faculty of Fisheries, BSMRAU, Bangladesh from 27 March 2013 to 30 June 2013. Twelve ponds were used for organic fish culture. Each pond area is approximately 202 m^2. Aquatic weed were removed manually. Repeated netting was done to remove undesirable fish species. Organic manure (semi-digested cow dung) was applied at the rate of 0.10~0.13 kg/m^2 to fertilize the ponds. The ponds were kept without stocking of fish for 5 days for production of plankton.

Three stocking ratios of grass carp to GIFT tilapia were tested (Table 1): grass carp at 0.6 fish/m^2 with GIFT tilapia at 0.3 fish/m^2 (T_1), grass carp at 0.6 fish/m^2 with GIFT tilapia at 0.6 fish/m^2 (T_2), grass carp at 0.6 fish/m^2 with GIFT tilapia at 0.9 fish/m^2 (T_3) and grass carp only at 0.6 fish/m^2 as control (T_4). Each treatment was triplicated. Grass carp fingerlings (14.6±1.5 ~ 17.9±2.9 g) were stocked on 27 March 2013, while GIFT tilapia fingerlings (12.9±1.3 ~ 15.6±1.2 g) were stocked 5 days later (31 March 2013). The total growing periods were 95 days for grass carp and 90 days for GIFT tilapia. Chopped fresh napier grass leaf was the sole nutrient input and provided twice daily in the morning and afternoon.

Table 1: Experimental design

Treatments	***No. of Replication***	***Stocking rate (fish/m²)***	
		Grass carp	***Tilapia***
T_1	3	0.6	0.3
T_2	3	0.6	0.6
T_3	3	0.6	0.9
T_4	3	0.6	-

The rate of fish growth is dependent on a number of factors including species, age, genetic potential, water temperature, health, and quantity and quality of food (Alyshbaev 2013, Kefi *et al*. 2014). Young fish are capable of doubling their weight in a much shorter time than when they are older due to a decrease in potential growth rates (Alyshbaev 2013). It is therefore useful to be able to ascertain the rate at which fish are growing. The best method of doing this is to calculate the specific growth rate (SGR % day^{-1}), which is a measure of the percentage body weight increase per day (Alyshbaev 2013, Kefi *et al*. 2014). The SGR can be calculated using the following equation.

$$SGR\ (\%\ day^{-1}) = \frac{\ln(final\ weigth) - \ln\ (initial\ weight)}{culture\ periods\ (days)} \times 100$$

Two batches of fresh napier grass, with three replications in each batch, were analyzed for proximate composition using AOAC (1980). Similarly, two batches of fresh grass carp feces, one at the middle and the other at the end of the experiment, with three replications in each batch, were analyzed for proximate composition.

Fortnightly measurements of water quality parameters were conducted at 8 am – 10 am. Water temperature (Lutron PDO-519), dissolved oxygen (DO), and pH were measured fortnightly *in situ* using DO meter (HACH DO meter) and pH meter (HANNA pocket meter). Fortnightly growth measurements of grass carp and tilapia were done by randomly sampling at least 15% of both grass carp and tilapia.

A simple economic analysis (benefit cost ratio- BCR) was performed to estimate the net profit of cultured grass carp and monosex tilapia. BCR is the ratio between economic benefits and costs (EC 2008). Data were analyzed statistically by ANOVA using SPSS (version 17.0) statistical software package (SPSS Inc., Chicago). Differences were considered significant at an alpha level of 0.05.

RESULTS

Proximate composition (%) of fresh napier grass and fresh feces of grass carp are presented in Table 2. Chopped napier grass contained crude protein of 8.9% and crude fibre of 29.4%. In contrast, fresh feces of grass carp contained crude protein of 6.0% and crude fibre of 34.0%. The perennial nature, hardiness and low cost of production of napier grass are the major advantages for small resource-poor farmers.

Table 2: Proximate composition (%) of fresh napier grass and fresh feces of grass carp

Parameters	*Fresh napier grass*	*Fresh feces of grass carp*
Dry matter (%)	17.90±1.20	05.7±0.10
Crude protein (%)	08.90±0.60	06.0±0.20
Crude fiber (%)	29.40±0.20	34.0±0.30
Total lipids (%)	01.80±0.70	01.1±0.50
Ash (%)	11.30±0.90	07.8±0.60

The growth performance of aquatic organisms depends on the water quality of a water body. Water quality may affect aquatic production. pH values varied from 7.0 to 7. 6, indicating the suitable condition for fish culture (Figure 1). Temperature varied from 22.6 °C to 32.5 °C (Figure 2). The concentration of dissolved oxygen ranged from 4.3 mg/l to 6.8 mg/l (Figure 3).

The fortnight variation of mean weight of grass carp in different treatments is shown in Figure 4. The mean final weight (350.0±35.0 g) and specific growth rate (3.52±0.04) of grass carp in T_2 were significantly greater than those in other polyculture treatments during harvesting ($P < 0.05$, Table 3). There were no significant differences in final weight and SGR of grass carp ($P > 0.05$) among treatments T_1, T_3 and T_4. Survival rate of grass carp was not significantly different among the treatments ($P > 0.05$).

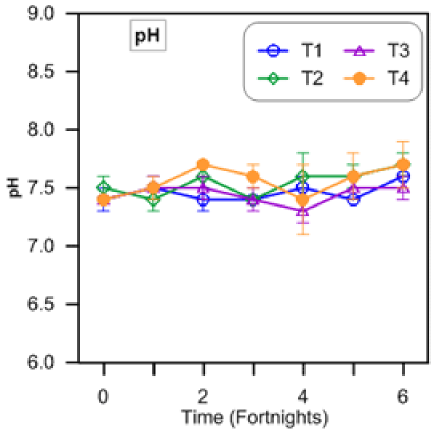

Figure 1: Fortnight variations of pH in the grass carp –tilapia polyculture ponds fed napier grass

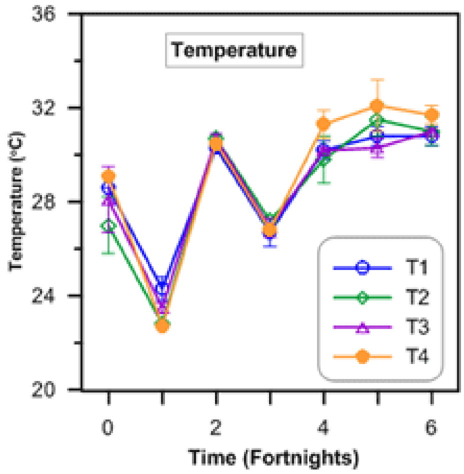

Figure 2: Fortnight variations of temperature in the grass carp–tilapia polyculture ponds fed napier grass

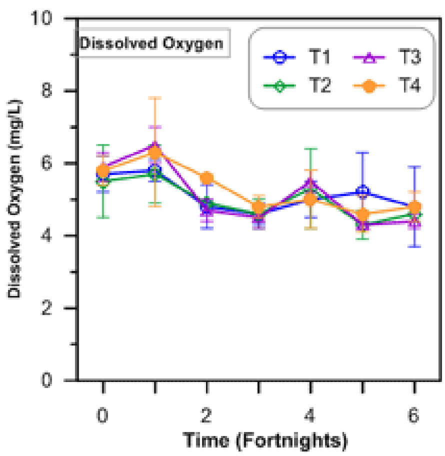

Figure 3: Fortnight variations of dissolved oxygen in the grass carp –tilapia polyculture ponds fed napier grass

Net fish yields (NFY) were the highest in treatment T_2 (1.86±0.5 t/ha/90 days), intermediate in treatments T_3 (1.47±0.3 t/ha/90 days) and T_4 (1.42±0.1 t/ha/90 days), and the lowest in treatment T_1 (1.40±0.3 t/ha/90 days) (P<0.05).

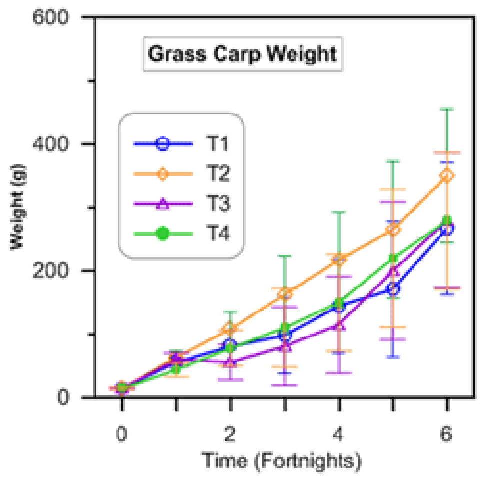

Figure 4: Mean weight of grass carp in different treatments during experimental period

Table 3: Stocking and harvest size, survival, growth and net fish yield (NFY) of grass carp and tilapia in different treatments fed with fresh chopped napier grass during the 90 days culture period

Item	*Treatment*			
	T_1	T_2	T_3	T_4
Grass Carp				
Initial mean weight (g/fish)	$14.6±1.5^a$	$17.9±2.9^a$	$16.7±1.2^a$	$14.9±1.7^a$
Final mean weight (g/fish)	$267.0±26.0^b$	$350.0±35.0^a$	$280.0±37.0^b$	$270.0±32.0^b$
Survival (%)	$82.6±4.8^a$	$83.2±4.09^a$	$80.8±3.59^a$	$81.3±5.12^a$
Daily weight gain (g/fish/ day)	$2.80±0.4^c$	$3.73±0.6^a$	$2.95±0.5^b$	$2.84±0.3^c$
SGR (% day^{-1})	$3.22±0.05^b$	$3.52±0.04^a$	$3.27±0.03^b$	$3.23±0.04^b$
NFY (t/ha)	$1.40±0.3^c$	$1.86±0.5^a$	$1.47±0.3^b$	$1.42±0.1^c$
Tilapia				
Initial mean weight (g/fish)	$13.7±0.5^a$	$15.6±1.2^a$	$12.9±1.3^a$	-
Final mean weight (g/fish)	$181.0±4.0^a$	$168.0±3.0^b$	$131.0±7.0^c$	-
Survival (%)	$81.4±2.56^a$	$82.0±3.14^a$	$79.8±3.78^a$	-
Daily weight gain (g/fish/day)	$1.86±0.5^a$	$1.71±0.4^b$	$1.30±0.6^c$	-
SGR (% day^{-1})	$2.87±0.3^a$	$2.79±0.2^b$	$2.51±0.3^c$	-
NFY (t/ha)	$0.52±0.1^a$	$0.86±0.1^b$	$0.94±0.2^c$	-
Combined fish yield				
NFY (t/ha)	$1.92±0.08^c$	$2.72±0.2^a$	$2.42±0.4^b$	$1.42±0.1^d$

Mean values with different superscript letters in the same row are significantly different (P<0.05).

The fortnight variation of mean weight of tilapia in different treatments is shown in Figure 5. The mean final weights of GIFT tilapia were significantly different among the treatments (P<0.05, Table 3). Survival rate of tilapia was not significantly different among the treatments (P>0.05). The daily weight gains, SGR and NFY of tilapia were significantly differing among the treatments (P<0.05). The combined net fish yields of grass carp and tilapia were significantly different among all treatments. The combined NFY were the highest in treatment T_2 (2.72±0.2 t/ha/90 days), intermediate in treatments T_1 (1.92±0.08 t/ha/90 days) and T_3 (2.42±0.4 t/ha/90 days), and the lowest in treatment T_4 (1.42±0.1 t/ha/90 days) (P<0.05).

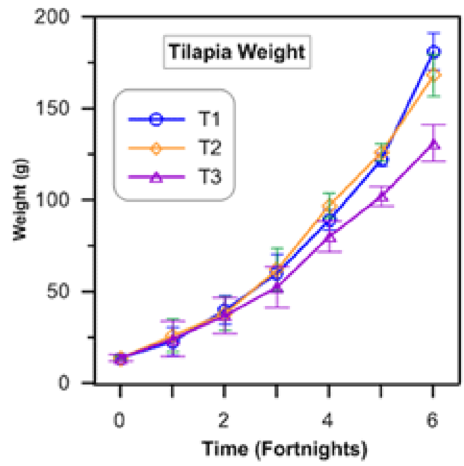

Figure 5: Mean weight of tilapia in different treatments during experimental period

Input costs were significantly higher (P<0.05) in treatment T3 compared to treatments T_1, T_2 and T_4 (Table 4). The combined yield of grass carp and tilapia at the end of 90 days culture period was significantly higher (P<0.05) in treatment T_2 (2.72 t/ha/90 days) compared to treatments T_1 (1.92 t/ha/90 days), T_3 (2.42 t/ha/90 days) and T_4 (1.42 t/ha/90 days).

Table 4: ANOVA for key variables of fish production and economic analysis during 90 days of study

Parameter	*Treatment*			
	T_1	T_2	T_3	T_4
Yield (t/ha)	$1.92±0.05^c$	$2.72±0.04^a$	$2.42±0.06^b$	$1.42±0.07^d$
Input cost (10^4 BDT/ha)	$11.57±0.1^c$	$12.31±0.2^b$	$13.06±0.1^a$	$10.46±0.15^d$
Gross income (10^4 BDT/ha)	$14.13±0.01^c$	$19.54±0.12^a$	$16.70±0.16^b$	$10.64±0.11^d$
Gross margin (10^4 BDT/ha)	$2.55±0.11^c$	$7.23±0.18^a$	$3.64±0.14^b$	$0.34±16^d$
BCR	$0.22±0.06^b$	$0.59±0.09^a$	$0.28±0.14^b$	$0.03±0.11^c$

Gross income in polyculture of grass carp and tilapia with stocking ratio of 1:1 (T_2) was higher ($P<0.05$) compared to other stocking ratios (T_1, T_3 and T_4). On the basis of benefit-cost-ratio (BCR), gross margins were significantly higher ($P<0.05$) in treatment T_2 than that of treatments T_1, T_3 and T_4. The result indicates that the farmer's income will be double in the production of organic grass carp and tilapia with stocking ratio of 1:1 (T_2).

DISCUSSION

The water temperature, dissolved oxygen (DO) and pH of the experimental ponds did not show significant difference ($P>0.05$). Rahman (1992) reported that the range of pH of a suitable water body for fish culture would be 6.5 to 8.5. pH at each sampling dates were found within a suitable range for fish production. Wahab *et al*. (1995) recorded the water temperature from 27.2 °C to 32.4 °C in their experimental ponds. Kohinoor (2000) recorded a temperature range from 18.5 °C to 33.3 °C in polyculture system. The results of this study shows consistency with the previous study. In contrast, DO concentrations were a decreasing trend in most of the treatments. The greater load of grass carp wastes in ponds caused lower levels of dissolved oxygen, due probably to the decomposition of grass carp wastes at the end of the culture period as well the increasing trend of temperature towards peak summer season. The suitable range of dissolved oxygen for fish culture should be 5.0 mg/l to 8.0 mg/l (DOF 1996). The concentration of dissolved oxygen of this study shows consistency with the recommended range.

Worldwide attention has been increased on using organic foodstuffs including fish. The organic fish farming is a holistic management system (HMS). HMS enhances agro-ecosystem health including biodiversity, biological cycle and soil biological activity (Bjorklund *et al*. 1990). Organic fish production system is socially, ecologically and economically sustainable.

The napier grass was used in this experiment as biofertilizer. A major portion of plant biomass consumed by grass carp returns to the pond as organic manure stimulates plankton production for other planktivorous fish like as tilapia. From this study, it has been observed that *Pennisetum purpureum* fed grass carp attained a daily growth increment ranging from 2.80 to 3.73 g/day. This daily growth increment shows consistency with the study of Pandit *et al*. (2004). However, this growth increment of grass carp was higher than that of the grass carp (1.65 g/day) fed with *Azolla* (Majhi *et al*. 2006). The SGR ranged from 3.23 to 3.52 for grass carp and from 2.51 to 2.87 for tilapia. SGR can be greater than 3 at first feeding while fish over 1.0 kg have average values of 1 (Alyshbaev 2013). This is because smaller fish are capable of eating a much greater percentage of their body weight per day.

The production of grass carp in different combinations with GIFT tilapia ranged from 1.40 to 1.86 t/ha/90 days. The production of grass carp in the present study was higher than that of 0.93±0.1 to 1.13±0.5 t/ha/90 days reported in grass carp monoculture and polyculture fed with napier grass and stocked at 1 fish/m^2 (Shrestha and Yadav 1998, Shrestha 1999). However, the growth (1.30-1.86 g/day) and yields (0.52-0.94 t/ha/90 days) of tilapia in the present study were lower than those of commonly achieved in fertilized or manured ponds (Lin *et al*. 1997). This is because napier grass directly fed to grass carp and tilapia growth depended on natural food production derived from recycling of grass carp wastes.

Pandit *et al.* (2004) found that the growth and yields of Nile tilapia in polyculture with grass carp were lower due to recruitment of Nile tilapia fry through prolific breeding and resultant food competition diminishes growth and production of tilapia. In this study, the prolific breeder Nile tilapia was replaced by fast growth monosex GIFT tilapia (only male) to avoid recruitment of new tilapia population. As a result, the yield of monosex GIFT tilapia in the present study was higher (0.52 ~ 0.86 t/ha/90 days) than that of Nile tilapia (0.1 ~ 0.34 t/ha/90 days) examined by Pandit *et al*. (2004).

The present study has showed that the optimal ratio of grass carp to tilapia in polyculture fed napier grass was 1:1 (T_2). This indicated that the addition of tilapia to the grass carp ponds fed napier grass as the sole nutrient input can efficiently utilize available resources, reuse wastes derived from grass carp. Grass carp–tilapia polyculture fed napier grass was a low-cost alternative aquaculture system for small-scale poor farmers. However, the feeding rate of napier grass and stocking enhance the total fish production. The present study has also demonstrated that the stocking density of grass carp should be further studied.

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