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Effects of Napier Grass (*Pennisetum purpureum*) on Organic Carp Fish Production

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ABSTRACT

Inorganic aquaculture system, Napier grass (*Pennisetum purpureum*) provides the use of a holistic farming system based on partnership with nature. Therefore, in this study, we assessed the water quality parameter, growth performance parameter, and production of carp fishes in a polyculture system feeding Napier grass, and analyzed the benefit-cost ratio of grass carp (*Ctenopharyngodon idella*) and other carp fishes production using Napier grass under different stocking density with three treatments (T_1, T_2, T_3) each with three replications following a randomized complete block design from July 2018 to June 2019. Stocking density was 1250 fish ha^{-1} (T_1), 2500 fish ha^{-1} (T_2), and 3750 fish ha^{-1} (T_3) for grass carp. Catla (*Catla catla*), common carp (*Cyprinus carpio*) and mirror carp (*Cyprinus carpio carpio*) were stocked along with grass carp at the rate of 1250 fish ha^{-1} for all treatments. Water quality parameters such as temperature, dissolved oxygen, pH, nitrite, nitrate, phosphate, and ammonia were within the suitable range for culture. No significant differences (p>0.05) were found among the treatments. The gross production was significantly higher in T_3 (6.1-ton ha^{-1} year^{-1}) followed by T_2 (3.9-ton ha^{-1} year^{-1}) and T_1 (1.9-ton ha^{-1} year^{-1}). The cost-benefit analysis revealed that the net income significantly varied (p<0.05) among three treatments (659.0, 2569.8, and 5031.5 USD ha^{-1} year^{-1} in T_1, T_2 and T_3, respectively). From the economic point of view, better production and income of grass carp, catla, common carp, and mirror carp were estimated in T_3 as the stocking density of grass carp was higher in T_3 resulting in higher feces production caused higher plankton production in T_3 ponds. The results imply that Napier grass can be used as a food source to replace commercial fish feed in the regular diet of grass carp without compromising the growth of fish and the potential for safe use in aquaculture.

INTRODUCTION

Aquaculture has made a significant contribution to total fish production in Bangladesh and nowadays, organic aquaculture is the time demanding aquaculture practice all over the world and in Bangladesh, due to the healthy fish production (Mente *et al.*, 2011). However, feed and feeding are crucial elements that influence economical and sustainable aquaculture. Feed cost accounts for over 50% of the production cost in aquaculture. The principle of organic aquaculture is consisting of the production of aquatic organisms under defined farming conditions minimizing the negative impacts of external inputs (feed, environment, farming technologies, etc.) and farming impacts upon the surrounding (natural) environment. Therefore, organic aquaculture has already been attracted due to consumers' awareness of environmental degradation, health risks, and sustainability (Biao, 2008). Consumer demand for organic products is growing faster than supply. Although the growth rate of organic aquaculture products is unknown, the estimation ranges from 20% to 30% annually (Ruangpan, 2007). Therefore, many farmers have started shifting from traditional methods to organic cultivation for producing safe foodstuffs. The production of organic aquaculture is predicted to increase 240-fold by 2030, *i.e*., to an equivalent of 0.6% of the total estimated aquaculture production (FAO, 2002). Currently, integrated aquaculture systems may form the base of approved organic farming practices.

Organic farming favors lower input costs, conserving nonrenewable resources, the high market value of the organic fish, and thereby increase farm income (Majhi & Mandal, 2006 and Shaha *et al.*, 2015). The major problems in commercial fish farming are the use of antibiotics, chemicals, formulated feeds (containing poultry, tannery wastes as toxic heavy metals- mercury, lead, chromium etc.), indiscriminate feeding systems that pollute the surrounding aquatic environment (both fresh and marine) (Shaha *et al*., 2015). Only an organic fish farming system can virtually prohibit the utilization of synthetic chemicals, the use of heavy metal-containing feed in fish production (Majhi and Mandal, 2006). Napier grass is the potential organic source of fish food. Thus, organic aquaculture practices would help in raising aquatic organisms using napier grass without use of formulated feed in a human manner i.e. sustainable and pollution-free. Organic feed such as napier grass (*Pennisetum purpureum*) optimizes the health of the animal and reduces in reliance on drugs, including antibiotics. Additionally, napier grass has high nutritional value. Chopped napier grass contained 17.90 % dry matter, crude protein of 8.9%, crude fibre of 29.4 %, ash of 11.3%, and total lipids of 1.80% (Shaha *et al.,* 2015). The importance of organic farming is being recognized in developed countries all over the world (Shang and Tisdell, 1997; FAO, 2009).

Napier grass (*P. purpureum*) serves as low-cost supplemental feeds for fishes, especially grass that can easily be produced on the pond bank. Like other freshwater fish species, grass carp directly feed on these grasses. In addition, a major portion of plant biomass consumed by grass carp returns to the pond as organic manure that stimulates primary production. These primary production or plankton serve as food for fishes in the same pond. They are an excellent candidate to utilize these natural foods derived from plants fed to grass carp (Pandit *et al*., 2004). Carps are one of the most commonly cultured fishes in Bangladesh and belong to cyprinidae family. Among them, the Indian major carps, catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus cirrhosus*), and the Chinese major carps, grass carp (*Ctenopharyngodon idella*), bighead carp (*Aristichthys nobilis*) and silver carp (*Hypophthalmichthys molitrx*) are popular (Shrestha, *et. al.* 1996). Grass carp cultivation feeding with grasses can support the production of other fish species such as silver, bighead and common carps (Shrestha, 1999). The culture practices that are in operation for these species are mostly semi-intensive with varying levels of supplemental feeding (Sarder *et al.*, 2011). Grass carp is an herbivorous and commonly polyculture species in Bangladesh (Pandit *et al*., 2004). It consumes low-value vegetative waste and increases natural food production in the pond through nutrient recycling and fecal production (Yang *et al.*, 1990). As grass carp are known to feed on a wide variety of plants, the quantity and quality of natural food products derived from recycling of grass carp wastes depend largely on the type and input of forage provided.

With a long and rich history of integrated fish farming, China has been using grass and aquatic plants for feeding fish. These integrated systems are commonly found in many parts of China, particularly in the irrigated lowland areas (Cheng *et al*., 2016). Napier grasses (*P. purpureum*) is a species of perennial tropical grass native to the African grasslands. It can be consumed directly or indirectly by freshwater fish species such as grass carp (*C. idella*), bighead (*A. nobilis*), and common carp (*C. carpio*). Grass carp have pharyngeal teeth and are adapted to tearing plant material. This would be necessary as herbivorous fishes have to rely on the mechanical breakdown of plant cell walls. A major portion of plant biomass consumed by grass carp returns to the pond as organic manure that stimulates plankton production for other planktivorous fish in the same ponds (Pandit *et al*., 2004). Specifically, the presence of grass carp seems to be helpful in the bottom-dwelling common carp and mrigal. Napier grass is high-yielding-producing up to 300 t fresh weight/ha/season, and it can be easily produced on the farm serving as low-cost supplemental feeds for fish. The production cost can be halved for grass-fed fish, compared to cereal grain-fed fish, in terms of per kilogram of fish produced (FAO, 2001). Due to the fast growth of grass carp and compatibility with other carps, grass carp have been included in the polyculture of Indian and exotic carps commonly known as composite culture using commercially manufactured pelleted feeds. However, the growth and production performance of carp fishes cultured organically in a polyculture system using napier grass to grass carp fishes have not been determined yet. Presently the use of commercially manufactured pelleted feeds predominates in aquaculture (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). 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 an eco-friendly environment. Because, the production cost can be halved for grass-fed fish, compared to cereal grain-fed fish (FAO, 2001).

In this context, easily available or easily grown plant material is a prime need to reduce the production cost as well as to produce organic fish by maintaining an ecologically friendly environment (Bjorklund *et al*., 1990). However, very few systematic researches have been carried out on this aspect. Therefore, this study assessed the growth performance and production of carp fishes in a polyculture system feeding napier grass and analyzed the cost-benefit ratio of grass carp and other carp fishes production using napier grass in different stocking densities.

MATERIALS AND METHODS

Study area and experimental design

The experiment was conducted in the backyard ponds of the Faculty of Fisheries, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur (Figure. 1). To assess the effect of napier grass on carp fish production, a series of 9 earthen ponds (each pond 16m×12m×1.5m) were used for organic fish culture. The experiment was carried out for 12 months. Ponds were randomly selected for three treatments each with three replications following a randomized complete block design (Table 1).

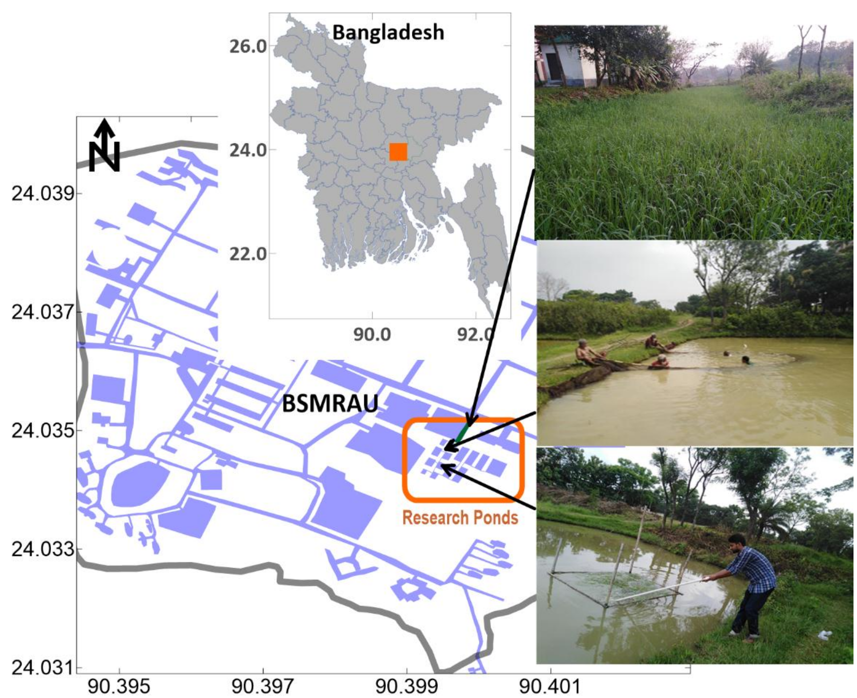


Fig. 1. Map showing research ponds at fisheries field complex of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU).

Table 1. Design of Experiment

Species cultured (fish/ha)	Treatments*		
	T_1	**T_2**	**T_3**
Grass carp	1250	2500	3750
Catla	1250	1250	1250
Common carp	1250	1250	1250
Mirror carp	1250	1250	1250

- Each treatment contains three replicates.

Pre-Stocking Management

Napier grass production

The low land adjacent to the Faculty of Fisheries was used for napier grass production. The land was prepared by ploughing with a bullock-drawn country plough. The length of cuttings of napier grass was 16-18 cm which contains at least 3 nodes in its sheath. Cutting napier grass was planted by line sowing and kept one node under the soil at 45° angle and maintain a row and plant spacing of 16 cm with a cutting rate of 16,000 cutting per hector. Organic manure (cow dung) was used at the rate of 130 tons/ha for land preparation. After 22 days of planting, cow dung was applied at the rate of 14.4-ton ha^{-1}. After 30 days of first cutting, cow dung was again applied at the rate of 14.4-ton ha^{-1}. After 60 days of the plantation, 14.4-ton ha^{-1} of cow dung was again applied. Grasses were firstly harvested above the ground level (3-5 cm) after 60 days of planting and then harvested regularly to ad libitum feed the fishes. Chopped napier grass contains crude protein 8.3-9.6%, crude fibre 28.2-29.6%, lipids 1.1-2.3% and ash 9.8-12.2% (Shaha *et al.,* 2015).

Pond Preparation

The ponds were free from aquatic vegetation and well exposed to sunlight. The main source of water in ponds was rainfall but had facilities to supply water from a big reservoir using a water pump whenever needed. Repeated netting was performed to remove undesirable fish species. Organic manure was applied at the rate of 4-5 kg $decimal^{-1}$ to fertilize the ponds. The ponds were treated with lime at the rate of 1.0 kg $decimal^{-1}$. The pond was kept without stocking of fish for 10 days for primary production.

Experimental species

The experimental fishes, grass carp (*C. idella*), catla (*C. catla*), common carp (*C. carpio*), and mirror carp (*C. carpio carpio)* were collected from Sagor Fish Hatchery, adjacent to the Bangladesh Fisheries Research Institute, Mymensingh. Prior to stocking, all fishes were kept in a hapa for conditioning, and the weight of fishes was recorded before releasing to the ponds.

Post stocking management

After the completion of the pond preparation, fishes were stocked in the pond at proper densities (Table 1). Finely chopped napier grass was provided ad libitum twice daily. The amount of napier grass provided to the treatments T_1, T_2 and T_3 were 2 kg/day, 2.5 kg/day, and 3 kg/day, respectively. Half the amount of napier grass is provided in the morning and the rest in the afternoon. Careful attention was also given to regular feeding during the whole experimental period. The napier grass was provided in the feeding ring to ease the feeding of fishes by saving their energy.

Analysis of water quality parameters

Various water quality parameter was recorded monthly. Physico-chemical parameter as water temperature ($^{\circ}$C), pH, dissolved oxygen (mg L^{-1}), nitrate-nitrogen (mg L^{-1}), nitrite-nitrogen (mg L^{-1}), phosphate-phosphorus (mg L^{-1}), ammonia-nitrogen (mg L^{-1}), and biological parameters such as phytoplankton density (cells L^{-1}), zooplankton density (cells L^{-1}) were measured monthly in the laboratory of Department of Fisheries Management, BSMRAU. Water and plankton samples were collected in black colored plastic bottles. Each bottle has a volume of 250 ml and marked with a respected pond number.

Physico-chemical parameters

Temperature dissolved oxygen (DO) of water was measured by a portable digital meter (Model: HACH- HQ40d) in the ponds. DO was measured at three different spots and under the feeding ring of each pond to observe the variation of DO levels due to the decomposition of napier grass deposited or settled. DO meter was calibrated before determination. pH of the water sample was measured using a digital pH meter (Model: sensION$^+$ EC71). pH meter was calibrated before the determination of water pH. Nutrient analyses including nitrite, nitrate, ammonia, and inorganic phosphate were carried out in the laboratory by spectrophotometric method (HACH, DR-6000, Germany, S/N: 1824775; HACH, 2008, 2012).

Biological parameter

Collection and preservation of plankton samples

For qualitative and quantitative study of phytoplankton and zooplankton, ten liters of water samples were randomly collected from five different locations of each pond and passed through a plankton net (mesh size of 55µm) and finally concentrated into 100 ml. Then concentrated samples were preserved in small plastic bottles with 10% buffered formalin and kept the samples in the refrigerator for further study.

Counting of plankton

Both phytoplankton and zooplankton were counted with the help of Sedgewick-Rafter counting Cell (S-R cell). From the concentrated samples, 1 ml was taken by a dropper and then put into the S-R cell. The counting chamber was covered with a coverslip in order to eliminate the air bubbles and left for about 5 minutes to allow the plankton to settle down and then studied under a compound microscope. According to Bellinger (1992) and Pennak (1953), the identification of plankton (both phytoplankton and zooplankton) was done up to the generic level. The plankton population was determined by the following formula (Stirling, 1985).

$$N = \frac{A \times 1000 \times C}{V \times F \times L}$$

Where, N= Number of plankton cells or units per liter of the original water, A= Total number of plankton counted, C=Volume of final concentrate of samples in ml, V= Volume of a field, F= Number of the fields counted, L= Volume of original water in liter. For each pond, the mean number of plankton recorded was expressed numerically in per liter of water.

Sampling of fish

Fishes were sampled monthly using a seine net. The monthly weight and length of about 30% of each species from each pond were measured to assess the health condition and growth of fishes. Weight was taken by using a portable balance.

Growth performance of fishes

At the end of the experiment, all fishes were harvested by repeated netting. Then the final growth of fishes was taken by measuring weight (g) of fish. The survival rates of fish for each treatment was calculated on the basis of number of fish harvested at the end of the experiment. The gross and net yield of fish for each treatment was determined by multiplying the average gain in weight of fish by the total number of fish survived in each treatment at the end of the experiment. The following equations were used to determine the growth parameter (Brown, 1957).

$$\text{Survival rate} = \frac{\text{Total number of fish harvest} \times 100}{\text{Total number of stock}}$$

Weight gain (g) = Final body weight (g) – Initial weight of fish (g)

$$\%\ \text{Weight gain} = \frac{\text{Final body weight (g)} - \text{Initial weight of fish (g)}}{\text{Initial weight of fish (g)}} \times 100$$

$$\text{Specific growth rate (\% per day)} = \frac{100 \times [\text{In (Final body weight)} - \text{In (Initial body weight)}]}{\text{Culture period (days)}}$$

$$\text{Gross production (ton per ha. per year)} = \frac{\text{Gross weight (kg) of fish}}{1000}$$

Cost-benefit analysis

A simple economic analysis was performed to estimate the net profit of cultured grass carp and other carp fishes. For this analysis, total input cost (cost of napier grass production, pond preparation, fingerlings transportation and fish harvesting), survival rate, yield of fish, total income and net income were calculated. The benefit cost ratio (BCR) was measured by using the following formula:

BCR= Total income / Total cost

Statistical analysis

The data of water quality and growth performance parameter of fishes were analyzed using R software (version R-4.1.3). If the $p < 0.05$, there were significant differences among the observed values.

RESULTS

Physico-chemical parameters

Water quality parameters such as temperature (27.6 to 32.2 ºC), pH (6.77 to 7.94), nitrite (0.003 to 0.008 mg L^{-1}), nitrate (0.01 to 0.06 mg L^{-1}), phosphate (0.03 to 0.21 mg L^{-1}) and ammonia (0.21 to 0.99 mg L^{-1}) were within the suitable range for fish production (Fig. 2). There was no significant variation among the treatments ($p > 0.05$). Dissolved oxygen concentration varied significantly between the feeding ring (WFR) and outside of the feeding ring (OFR) at different treatments (Fig. 3). Mean (±SD) dissolved oxygen was 6.30 ± 0.21, 6.41 ± 0.28, 6.28 ± 0.23 mg L^{-1} in treatments T_1, T_2, and T_3, respectively (Fig. 3). The DO concentrations were within suitable range in different treatments (Fig. 3).

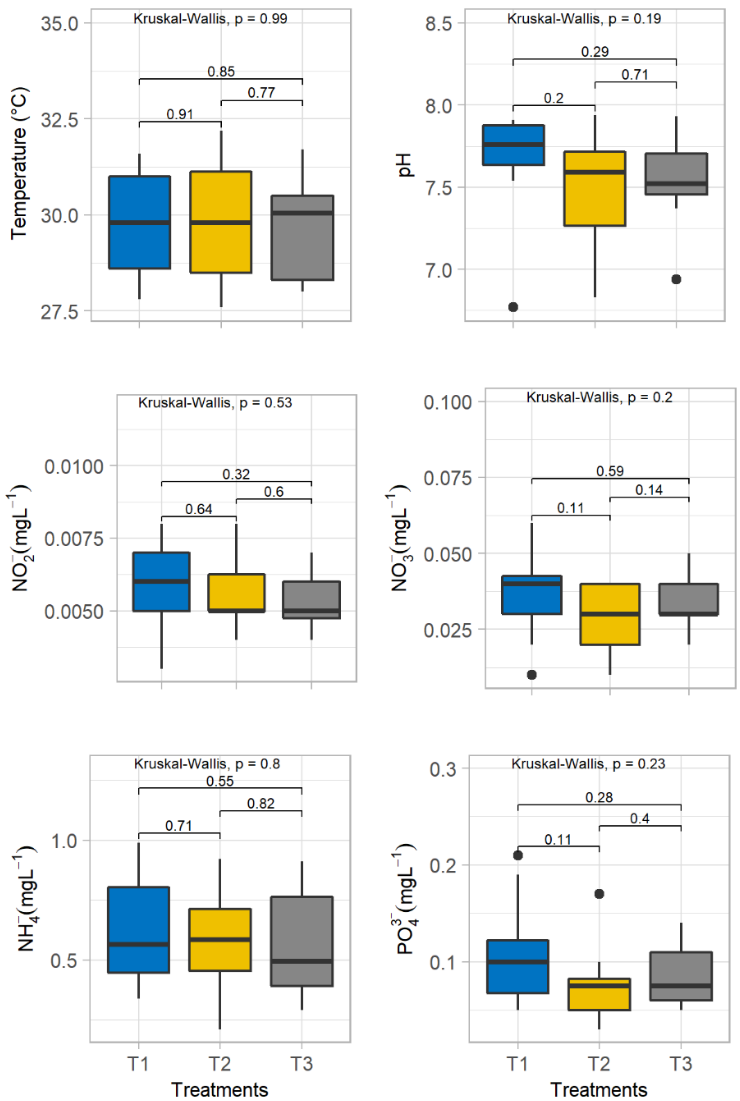


Fig. 2. Concentration of physico-chemical parameters in different treatments. T_1 indicates treatment-1, T_2 indicates treatment-2 and T_3 indicates treatment-3.

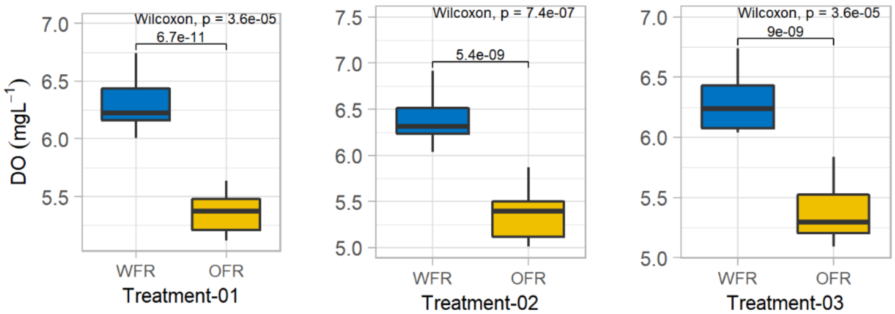


Fig. 3. Comparison of mean (±SD) dissolved oxygen concentration (mg L^{-1}) within the feeding ring (WFR) and outside the feeding ring (OFR) in different treatments. T1 indicates treatment-1, T2 indicates treatment-2 and T3 indicates treatment-3.

Biological parameter

Eighteen genera of phytoplankton of four families such as bacillariophyceae (5 sp.), chlorophyceae (9 sp.), cyanophyceae (2 sp.) and euglenophyceae (2 sp.) were identified in the experimental ponds (Fig. 4). Ten genera of zooplankton composition of the two families such as crustacea (6 sp.) and rotifera (4 sp.) were found in the experimental ponds. (Fig. 4). Plankton abundance varied among the ponds. The abundance of plankton varied from 1.25×10^3 to 3.87×10^3**;** 1.62×10^3 to 4.25×10^3 and 3.12×10^3 to 5.25×10^3 cells L^{-1} with mean (± SD) value of 2.30 ± 0.90 ($\times 10^3$); 2.77 ± 0.85 ($\times 10^3$) and 4.22 ± 0.65 ($\times 10^3$) cells L^{-1} in T_1, T_2 and T_3, respectively.

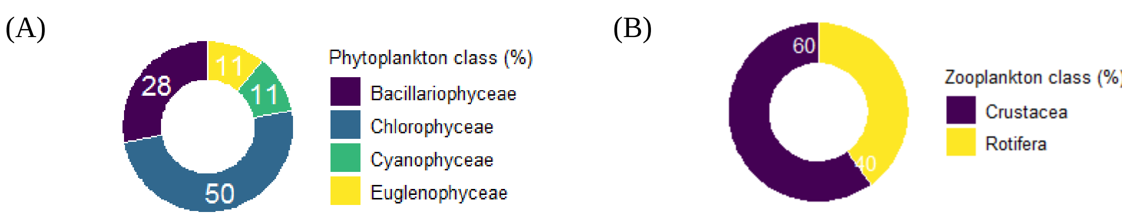
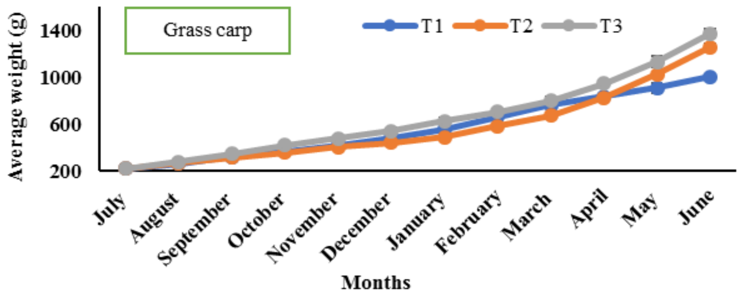


Fig. 4. Phytoplankton and zooplankton distribution in experimental ponds.

Growth performance of fishes

The monthly variations of mean weight of grass carp, catla, common carp and mirror carp of different treatments (T_1, T_2 and T_3) have showing in Fig. 5. Grass carp attained mean final weight of 1002.8 ± 14.36 g in T_1, 1259.1 ± 30.33 g in T_2 and 1373.8 ± 35.21 g in T_3 (Fig. 5). The highest growth was found in T_3 and the lowest growth in T_1. The percent weight gain and specific growth rate (SGR) of grass carp were significantly differed among the treatments ($p < 0.05$) (Fig. 5). The production of grass carp varied significantly ($p < 0.05$) among the treatments and the highest was found in T_3 (5.00 ± 0.08 ha year $^{-1}$ton^{-1}), whereas the lowest was in T_1 (1.22 ± 0.02 ha year $^{-1}$ton^{-1}).

(A)



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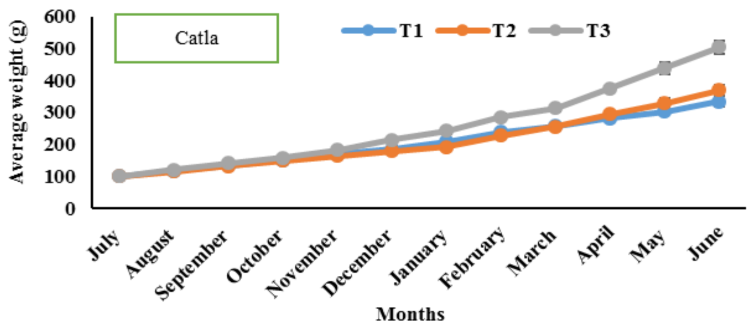

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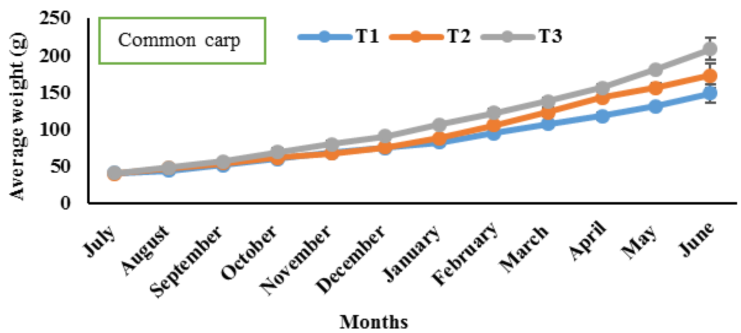

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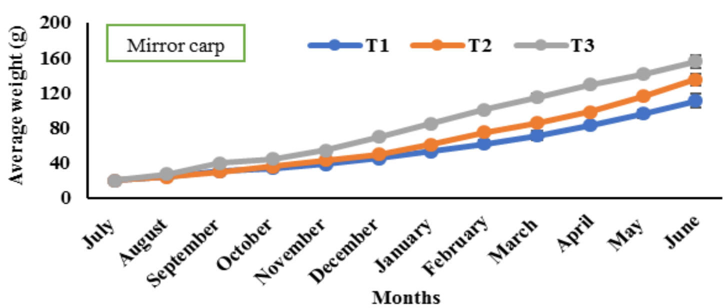

Fig. 5. Growth performance of cultured fishes under three treatments. T1 indicates treatment-1, T2 indicates treatment-2 and T3 indicates treatment-3.

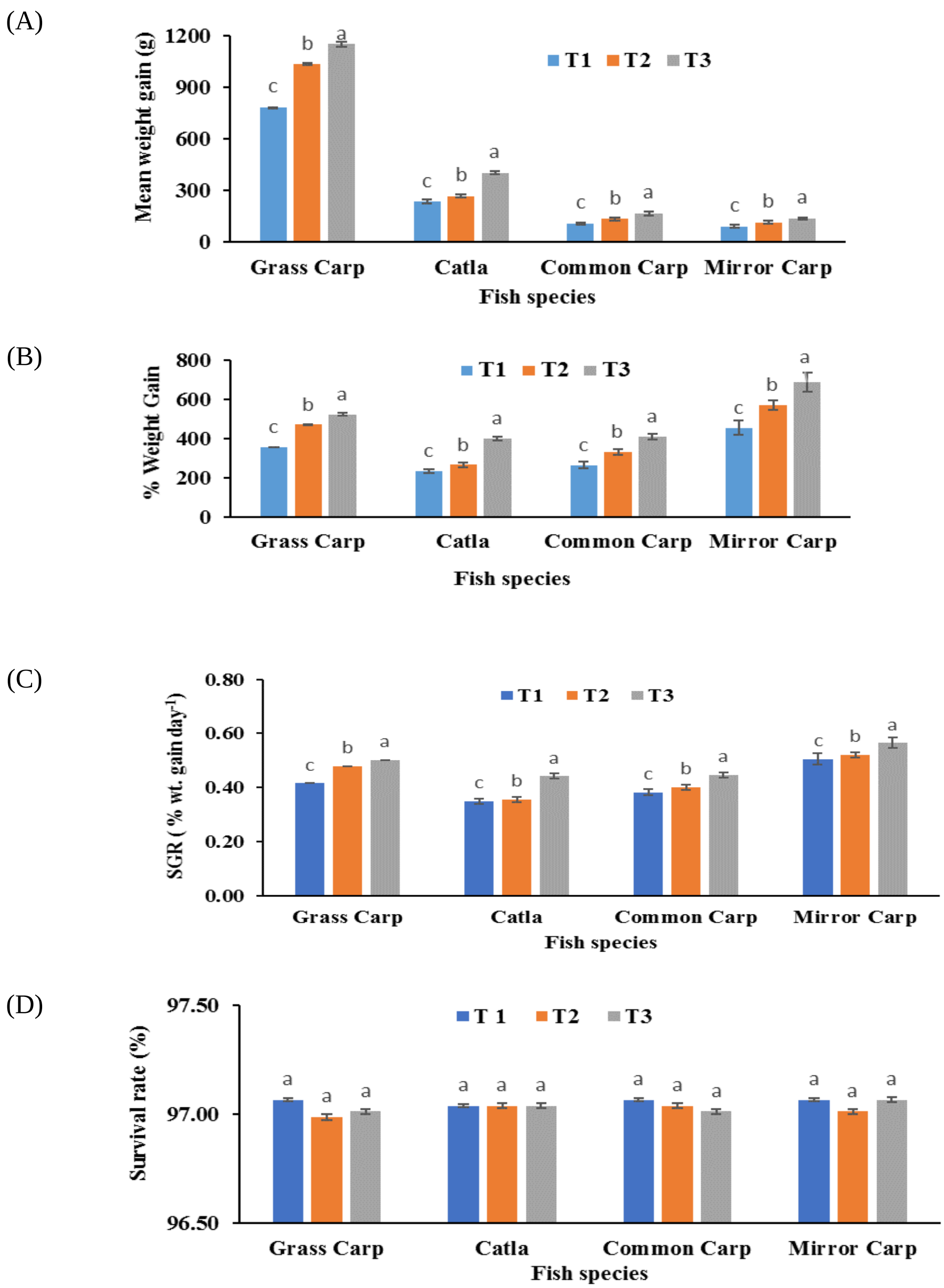

Fig. 6. Mean weight gain, % Weight gain, SGR, and Survival rate. Different letters indicate significant variations among the treatments ($p < 0.05$). Error bar = ±SD. T1 indicates treatment-1, T2 indicates treatment-2 and T3 indicates treatment-3.

Catla attained mean final weight of 335.2 ± 15.6 g in T_1, 368.9 ± 17.3 g in T_2 and 503.4 ± 20.1 g in T_3. The highest growth was found in T_3 and the lowest growth in T_1 (Fig. 6). The percent weight gains and SGR of catla were significantly differed among the treatments ($p < 0.05$) (Fig. 6). The production of catla were significantly different among all the treatments. The highest production of catla was found in T_3 (0.61 ± 0.02 ha year $^{-1}$ton^{-1}), whereas the lowest was in T_1 (0.41 ± 0.02 ha year $^{-1}$ton^{-1}) ($p < 0.05$). In contrast, common carp attained mean final weight of 148.5 ± 12.27 g in T_1, 172.6 ± 16.48 g in T_2 and 208.4 ± 14.98 g in T_3. The highest growth was recorded in T_3 whereas the lowest growth was in T_1 (Fig. 6). Survival rate of common carp was not significantly different among the treatments ($p > 0.05$). The percent weight gain and SGR of common carp were significantly differed among the treatments ($p < 0.05$) (Fig. 6). The production of common carp was significantly different among all treatments. The highest ($p < 0.05$) production was found in T_3 (0.25 ± 0.02 ha year $^{-1}$ton^{-1}), whereas the lowest was in T_1 (0.18 ± 0.01ha year $^{-1}$ton^{-1}).

Mean final weight of mirror carp was 111.2 ± 7.93 g in T_1, 135.4 ±6.35 g in T_2 and 155.9 ± 7.53 g in T_3 (Fig. 6). The percent weight gain and SGR of mirror carp were significantly differed among the treatments ($p < 0.05$). The production of mirror carp was significantly different among all treatments. The production of mirror carp was the highest ($p < 0.05$) in T_3 (0.19 ± 0.01 ha year $^{-1}$ton^{-1}), whereas the lowest in T_1 (0.13 ± 0.01 ha year $^{-1}$ton^{-1}).

There was highly significant difference ($p < 0.05$) in the mean weight gain of grass carp, catla, common carp and mirror carp in different treatments (Fig. 6). Percentage weight gain was 355.82 ± 1.38, 471.27 ± 2.75 and 523.60 ± 6.43 for grass carp; 234.74 ± 10.81, 266.51 ± 11.18 and 401.21 ± 10.63 for catla; 265.31 ± 16.16, 331.89 ± 14.03 and 409.72 ± 58 for common carp; and 455.48 ± 34.43, 571.03 ± 24.25 and 686.81 ± 49.87 for mirror carp in treatments $T_{1,}$ T_2 and $T_{3,}$ respectively. There was significant difference ($p < 0.05$) in the mean percentage weight gain of grass carp, catla, common carp and mirror carp in different treatments (Fig. 6).

Specific growth rate was 0.42 ± 0.00, 0.48 ± 0.00 and 0.50 ± 0.00 for grass carp; 0.35 ± 0.01, 0.36 ± 0.01 and 0.44 ± 0.01for catla; 0.38 ± 0.01, 0.40 ± 0.01 and 0.45 ± 0.01 for common carp; and 0.51 ± 0.02, 0.52 ± 0.01 and 0.56 ± 0.02 for mirror carp in treatments $T_{1,}$ T_2 and T_3 respectively. There were significant differences ($p < 0.05$) in the specific growth rate of grass carp, catla, common carp and mirror carp in different treatments (Fig. 6). There was no significant difference ($p > 0.05$) in the survival rate of grass carp, catla, common carp and mirror carp in different treatments (Fig. 6).

Fish Production (ton ha^{-1} year^{-1})

The gross fish production was 1.94 ± 0.05, 3.88 ± 0.02 and 6.05 ± 0.12-ton ha^{-1} year^{-1} in treatments T_1, T_2 and T_3 respectively (Fig. 7). The gross fish production varied significantly among the treatments. The highest fish production was recorded in T_1 followed by T_2 and T_1, respectively.

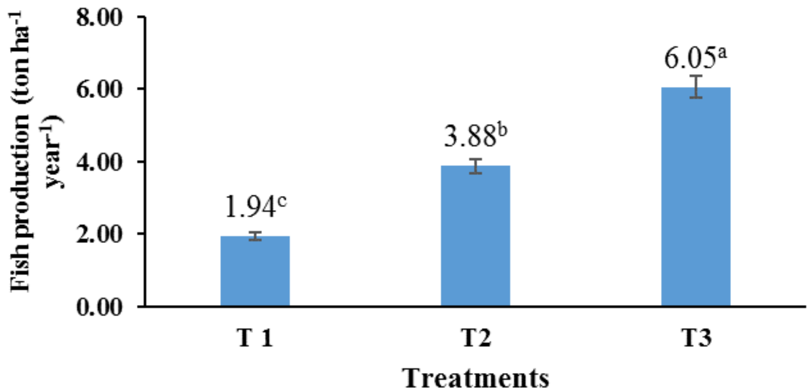

Fig. 7. Gross production of grass carp, catla, common carp and mirror carp among three treatments. Different letters indicate significant differences among the treatments ($p < 0.05$). Error bar = ±SD.

Table 2. Various inputs and their cost, cost for fish stocking, lime and napier grass during post-stocking management, netting cost, fingerling cost, gross income and net income

Items	**Amount (USD ha^{-1} year^{-1})**		
	T_1	**T_2**	**T_3**
Pond preparation	350.34	350.34	350.34
Lime	29.20	291.95	291.95
Napier grass	21.84	64.81	141.89
Feeding cost	280.27	350.34	420.41
Transport cost	116.78	175.17	233.56
Labour	116.78	140.14	163.49
Netting	268.60	326.99	385.38
Fingerling cost	875.86	1167.81	1459.76
Total Input cost	2059.67	2867.56	3446.79
Total output	2718.66	5437.33	8478.31
Net income	659.00	2569.77	5031.51

Economic analysis

Cost and returns were determined on the basis of various inputs, their cost and production (Table 2) In this study, the highest net income was 5031.51 USD ha^{-1} $year^{-1}$ for grass carp in treatment T_3 followed by $T_{1,}$ and T_2. The net market price of grass carp, catla, common carp and mirror carp were considered as USD 1.75 kg^{-1}, 1.40 kg^{-1}, 1.28 kg^{-1}, 1.17 kg^{-1}. Net income was 659.00, 2569.77 and 5031.51 USD ha^{-1} $year^{-1}$ in treatments $T_{1,}$ T_2 and T_3 respectively (Table 3), Both the gross income and net income were significantly higher in treatment T_3 compared to the treatments T_1 and T_2 (Fig. 8).

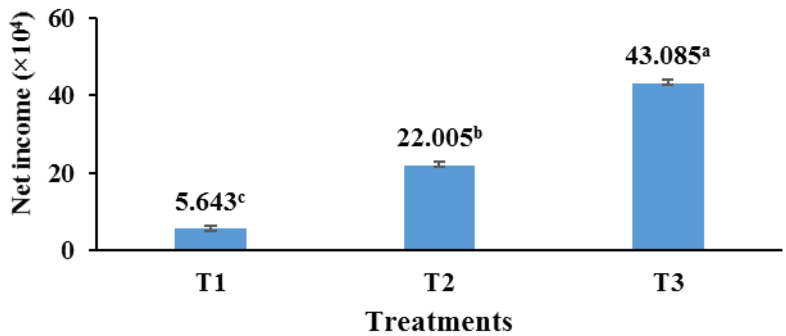

Fig. 8. Net income in different treatments during the experimental period.

Table 3. Cost-benefit comparison of grass carp, catla, common carp and mirror carp production under three treatments

Topic	Treatments		
	T_1	T_2	T_3
Gross production (ton ha^{-1} $year^{-1}$)	1.94 ± 0.05^c	3.88 ± 0.02^b	6.05 ± 0.12^a
Total input cost (USD ha $year^{-1}$)	2059.67^c	2867.56^{ab}	3446.79^a
Total income (USD ha $year^{-1}$)	2718.66^c	5437.33^b	8478.31^a
Net income (USD ha $year^{-1}$)	659.00^c	2569.77^b	5031.51^a
BCR	0.32^c	0.90^b	1.46^a

Different letters indicate significant variations among the treatments ($p < 0.05$). Error bar = ±SD.

DISCUSSION

The growth performance of aquatic organisms depends on the water quality of a water body. In aquaculture, good quality water is prerequisite for maximum yield (Bisht *et al.*, 2013). In the present study, no significant variation ($p > 0.05$) in physico-chemical parameters were found among the treatments. All the water quality parameters were found within the suitable ranges for fish culture (Markovic *et al.*, 2009; Bhatnagar and Devi, 2013; Nazish and Mateen 2010; Rahman, 1992). Bhatnagar and Singh (2010) reported that DO level > 5 ppm is essential for good fish production. DO concentration (mg L^{-1}) under the feeding ring was lower due to the decomposition of napier grass deposited in the bottom compared to DO concentration outside of the feeding ring (OFR) for all treatments (Fig. 3). The concentration of DO showed consistency with the recommended range. Higher plankton abundance was found in T_3 compared to T_1 and T_2. This is because grass carp consumed more napier grass in T_3 than other treatments (T_2 and T_2) and produced more feces acting as sole nutrient for primary production. As a consequence, better growth of grass carp and other carp fishes was found in treatment T_3 than treatment T_1 and T_2, respectively. Thus napier grass acted as biofertilizer as a major portion of plant biomass consumed by grass carp returned to the pond as organic manure that stimulated plankton production for other planktivorous carp fishes (Sharmin, 2013).

The present bundle of scientific aquaculture procedures provides a high-cost technology that constitutes a key barrier in this type of farming, particularly to the small-scale and resource-poor farmers in many developing nations like Bangladesh. Despite the fact that chopped napier grass contained 9.2% of crude protein and 28.6% crude fibre, its perennial nature, hardness and inexpensive cost of production are the primary benefits for small farmers with limited resources (Pandit *et al*., 2004). The productions of grass carp and other carp species fed napier grass differed significantly in the current investigation. The differences in growth of grass carp and other carps could be attributed to the amount of napier grass provided to them. The increased growth of grass carp in this study could be owing to the presence of plant materials rich in primary and secondary metabolites (Sangeetha and Rajendran 2019). Researchers from the past have made similar observations (Citarasu, 2010; Ji *et al*., 2007; Johnson and Banerji, 2007; Luo *et al*., 2004; Rawling *et al*., 2009; Turan 2006). Green fodder feeding helps to prevent fatty liver disease and promotes fish growth (Huang and Huang, 1992; Raa *et al.*, 1982).

Protein is the most critical component impacting fish development performance and feed cost, according to Luo *et al*. (2004). To boost food conversion efficiency and thus fish development, new substances are added to fish feed (Fernandez-Navarro *et al*., 2006). Ji *et al*. (2007) obtained better growth in sea bream using several plants as feed additives which improved nile tilapia growth and survival. When juvenile perk perch were fed a medicinal herb mixed diet, there was a substantial difference in growth performance and body composition (Zakes *et al*., 2008). Fish with a diet rich in greed tea extract grew faster, had better body composition, and were less stressed (Hwang *et al*., 1992). Tilapia growth performance was significantly influenced by the use of plant leaves as a feed ingredient (Dada and Ikuerowo, 2015; Feng *et al*., 2008). Higher grass carp muscle, with higher protein content and a lower crude fat level was observed when the fish fed with mixture of hybrid napier grass and feed (Feng *et al*., 2008; Yu *et al*., 2018). In this study, grass carp and other carp species fed napier grass grew faster and gained more weight. As a result, napier grass supplementation appears to be appropriate for grass carp polyculture.

In the present study, the highest net income was found in treatment T_3 followed by T_1, and T_2. Thus, the present study suggests that utilizing napier grass as sole nutrients for producing organic grass carp, catla, common carp and mirror carp is economically viable for the fish farmer. Shaha *et al.* (2015) evaluated the production of organic grass carp (*Ctenopharyngodon idella*) and GIFT tilapia (*Oreochromis niloticus*) using napier grass, *Pennisetum purpureum*.

CONCLUSION

Use of napier grass in fish ponds is important for sustainable aquaculture through reducing expenditure on costly feeds and inorganic fertilizers which form more than 50% of the total input costs. The present study showed that growth and production performance of grass carp and other carp fishes in polyculture system was higher in stocking density of 3750 fish ha^{-1} in treatment T_3. Napier grass was used as a sole nutrient input for other carp fishes. Based on cost-benefit analysis it was found that the highest net income was 5031.5 USD ha^{-1} $year^{-1}$ in treatment T_3. The finding of the study will reduce the aquaculture cost, conserve nonrenewable resources, help to get high market value of the organic fish and thereby increase income of fish farmers. Thus, fish farmers will be benefited and uplift their socio-economic condition through producing organic fish that will maintain ecologically-friendly environment.

AUTHORS CONTRIBUTIONS

Dinesh Chandra Shaha: Designed the experiments; Funding acquisition; Preparation of the map of the study area; Analyzed and interpreted the data; Review and editing; **Md. Hafij Al Asad:** Performed the experiments; Analyzed and interpreted the data; Manuscript preparation; **Jahid Hasan:** Review and editing **Nahida Islam:** Review and editing; **Farhana Haque:** Review the manuscript and guidance; **Sabuj Kanti Mazumder:** Review and editing.

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COMPETING INTERESTS

All the data were collected according to legal provisions only. The authors declare that they have no conflict of interest.

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