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Research Article

Enhancing Growth Performance of Grass Carp (*Ctenopharyngodon idella*) and Tilapia (*Oreochromis niloticus*) with German Grass (*Holcus mollis*) and Vermicompost

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Abstract

In the present study, we evaluated the growth performance of grass carp (*Ctenopharyngodon idella*) and tilapia (*Oreochromis niloticus*) feeding German grass (*Holcus mollis*) produced organically using vermicompost. There were three treatments in the experiment, only German grass (T_1), German grass + vermicompost @ 8,000 kg ha^{-1} year^{-1} (T_2) and German grass + vermicompost @ 16,000 kg ha^{-1} year^{-1} (T_3). In treatment T_2 and T_3, 25 % vermicompost was applied prior to 15 days ahead of fish stocking. The fish was stocked @ 10,000 grass carps and 15,000 tilapia ha^{-1}, respectively. Water quality parameter such as temperature, dissolved oxygen, pH, nitrite, nitrate, and phosphate were varied among the treatments. 29 phytoplankton and 9 zooplankton genera observed in the three treatments with a significant abundance ($p < 0.05$) in vermicompost treated ponds. According to a gut content study, tilapia primarily fed zooplankton and phytoplankton, whereas grass carp pre-dominantly consumed German grass and phytoplankton. The gross production was significantly higher in treatment T_3 (2.94 Ton ha^{-1}) followed by T_2 (2.78 Ton ha^{-1}) and T_1 (2.57 Ton ha^{-1}) 77 days^{-1}. The research disclosed that the vermicompost application at 16,000 kg/ha/year with German grass was better option of producing organic grass carp and tilapia.

Introduction

Most of the aquaculture productions in developing countries are practiced in rural areas using semi-intensive fish pond culture systems. Aquaculture plays a major role in improving livelihoods, enhancing social equity, advancing gender equality, contributing to global food production (food and nutritional security), and promoting regional economies (Musyoka and Nairuti, 2021). Nevertheless, the significant role played by aquaculture and the increasing demand of aquatic organisms as well as the advancement in science and technology, fish farming in most developing countries is still at infancy stages. Fish feed challenge has been identified as one of the limitations to the commercialization of aquaculture, particularly in Africa (Zakaria et al., 2013). This is because farmers prefer and highly depend on fishmeal as the main protein source due to its superior nutritional properties, palatability, and biological value. Consequently, the majority of the farmers do not achieve their full potential due to the cost, scarcity, and ecological implications associated with obtaining the fishmeal (Shrestha, 1999). Nowadays, organic aquaculture is the time demanding aquaculture practice all over the world and in Bangladesh, due to the healthy fish production (Shaha et al., 2022). Therefore, there is a need to adopt economically and ecologically sustainable organic fertilizers such as vermicompost, which has no biosafety

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concerns (Vodounnou et al., 2016; Jambhekar, 1992). Vermicomposting has been recognized as a natural and cheap biotechnique of treating and bio-transforming organic wastes to safe and steady biofertilizers with the potential to promote aquaculture nutrition. Vermicompost contains macro and micro nutrients, vitamins, enzymes, antibiotics, hormones (Saefurahman et al., 2021; Verma et al., 2012). Like other organisms, fish also need food and supplements for their survival. Nutrients needed by fish include carbohydrates, proteins, fats, vitamins, enzyme and minerals, which can be found in vermicompost (Mohanty et al., 2019; Akter, 2012; Kumar et al., 2007; Bhusan and Yadav, 2003; Bhawalkar and Bhawalkar, 1993). 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 (Shaha et al., 2022). Organic farming favors lower input costs, conserving nonrenewable resources, the high market value of the organic fish, and thereby increases farm income (Jhingran, 1995). 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).

Fertilization is undertaken to improve the growth and reproduction of natural food organisms, which include zooplanktons, phytoplanktons, bacteria, microscopic algae, and insects. These natural organisms in water are eaten directly or indirectly depending on the fish-eating behaviors. For example, the herbivorous fish (such as carps) feed on algae and bacteria biomass, the carnivores (such as catfish) consume zooplanktons and insects, while omnivorous fish (such as tilapia) feed on all (Silva and Hasan, 2007; Feng et al., 2005; Kumar et al., 2005; Ispir et al., 2011). In contrast, German grass, also called creeping soft grass, is a high yielding perennial tropical grass (Wiersema 2013). Plankton, a natural source of food for fish, can be boosted by fertilization (Chakrabarty et al., 2009; Abbas and Hafeez-Ur-Rehman, 2005). All aquatic organisms depend on plankton as their primary source of nutrition. Herbivorous fish waste can be used to enrich the water and increase the amount of plankton that filter-feeding fish consume (Kumar et al., 2005). Tilapia can be cultured in both mono and polyculture however; polyculture of tilapia gives higher production than that of monoculture system (Khouraiba et al., 1991; Muendo et al., 2006). On the other hand, the exotic grass carp has got the popularity due to its fast growth and unique food habits. This fish has already been accepted as an important species in the polyculture systems in Bangladesh (Goyal et al., 2005).

There is little information regarding the use of vermicompost and German grass on fish culture (Saefurahman et al., 2021; Musyoka and Nairuti, 2021). However, none of this research demonstrated that the use of vermicompost and German grass on tilapia and grass carp fish. Hence, the present study was undertaken to analyze the spatial and temporal variations of water quality, to identify productivity of tilapia and grass carp, and to see the composition of gut content of tilapia and grass carp using vermicompost and German grass.

Materials and Methods

Experimental site

The experiment was carried out for 77 days from September to December 2014 in the fish ponds (16m×12m×1.5m) at Faculty of Fisheries, Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Gazipur-1706. T_1 (G_o) treatment was used as control with only German grass. Vermicompost is used as manure where 8,000 kg ha^{-1} year^{-1} is the rate of dose in treatment T_2 (G_o+VC_8) and 16,000 kg ha^{-1} year^{-1} in treatment T_3 (G_o+VC_{16}) sequentially.

Vermicompost preparation

Cow dung was the key raw materials of the production of vermicompost. Red earthworms *(Eisenia foetida*) were chosen for the production of vermicompost because of its rapid rate of multiplication and resulting conversion of organic matter where vermicompost is prepared from organic matter within 50-60 days. Vermicompost became ready within 50-60 days and stored after drying chemical composition of vermicompost was tested in the Soil Science Laboratory, Faculty of Agriculture, BSMRAU.

German grass production

German grass cuttings were planted via line sowing with one node at a 45° angle and a row to row and plant to plant gap was of 16 cm apart, cutting rate was 16,000 cuttings per hectare. 130 tons of cow dung per hectare were applied during the land preparation. Cow dung was given after 22 days of sowing at a rate of 14.4 tons per hectare. Cow dung was spread once more at a rate of 14.4 tons per hectare after the initial cutting had taken place within 30 days. Following 60 days of planting, grass was first cut above the ground of 3-5 cm, and it was then periodically cut for fish food. German grass samples were taken for proximate composition analysis.

Collection and preparation of grass samples for proximate composition analysis

Plant sample that had just been picked was cut into little pieces up to 1-2 cm, weighed, and sun dried for two to three days. The samples were stored in a drying oven at a temperature of 105°C for estimating dry matter. Then a porcelain grinder was used to grind the dried samples. The samples were preserved in a polythene bag after being ground, labeled, and kept for proximate composition analysis (Moisture, ash, crude protein, crude lipid). The analysis was carried out in the nutrition laboratory of the Department of Aquaculture at BSMRAU, Gazipur, using the methodology recommended by the association of official analytical chemists (Horwitz, 1984), with a few simple modifications.

Fish stocking

Fingerlings of grass carp and tilapia were stocked on 21 September, 2014. The fingerlings were collected from Sagor Fish Hatchery, Fishery Mor, BFRI, Mymensingh. Grass carp and tilapia were stocked at 10,000 nos. ha^{-1} and 15,000 nos. ha^{-1} rate respectively.

Feeding and manuring

Two times a day, in the morning and the afternoon, were crucial for observing noteworthy alterations in the pond environment, as well as any unusual fish activity and changes in the water's color. Throughout the whole trial period, careful consideration was also paid to regular eating. Finely chopped German grass was provided ad libitum twice a day, in the morning and the afternoon, to ensure the fish grew healthily. In order to facilitate fish feeding by conserving energy, grass was added to the feeding ring. The experimental ponds were fertilized with weekly dosages of vermicompost (Table 1).

Table 1. Manuring schedule (per-pond) in different treatments

Treatments (manure)	Total dose (kg)	Initial dose (kg)	Weekly dose (kg)
Control (German grass)	-	-	-
German grass+VC_8	19.8	4.95	1.35
German grass + VC_{16}	39.6	9.90	2.70

Sample Collection and Laboratory Analysis

Surface water was sampled within a depth of 0–0.5 m (euphotic layer) using a 1.5 L water sampler (Wildco-1520) for environmental parameter (DO, pH, temperature, nitrate, nitrite, phosphate) determination, immediately filtered through Whatman GF/F (0.45) filter paper using a vacuum machine and refrigerated under dark conditions until laboratory analysis. DO meter (HACH HQ30d) was used to measure dissolved oxygen and pH determined by a pH meter (sensION+ EC71). Nutrient analysis, including estimation of nitrite, nitrate and phosphate, was carried out in the laboratory and the values were determined by a spectrophotometric method (HACH, DR-6000, Germany, S/N: 1824775). Plankton samples were collected by trawling a 25 µm mesh size plankton net horizontally. The crude samples were transferred into a 150 mL black plastic bottle and preserved using Lugol's solution. According to APHA (1992), Bellinger (1992), and Peenak (1993), plankton identification was accomplished up to the generic level. Plankton population was estimated by the following formula (Clasceri et al., 1989).

Sampling of fish

Fishes were sampled fortnightly by using cast net. About ten fish of each species from every pond were measured for length and weight to check the growth and health of the fish.

Gut content analysis

Ten grass carp and ten tilapia were sampled randomly from every pond during harvest for gut content analysis.

Food and feeding observation

The stomach content analysis was carried out in the laboratory. These were collected from live fishes. The stomach was lengthwise cut, and the contents were put into a Petri dish. Then the stomach contents were preserved in 5% neutralized formalin for further analysis. Individual gut contents were then kept for five minutes to remove excess formalin and then analyzed using a binocular microscope to identify the make-up of the fishes' food.

SGR, survival rate and yield of fish

The number of fish caught at the end of the experiment served as the foundation for determining the fish survival rates for each treatment and replication. By dividing the average growth in fish weight (gross and net) by the survival rate in each treatment at the end of the experiment, the gross and net yield of fish for each treatment was obtained. The following equations were used to determine the growth parameter (Brown, 1957).

Statistical analysis

Statistical descriptive statistics (mean, range, and standard error) were determined for all of the environmental variables, grass carp and tilapia using SPSS v. 20. Two-way ANOVA performed in SPSS 22.0 to determine if there were statistically significant spatial and temporal differences of environmental variables and fish growth pattern.

Results and Discussion

Composition of vermicompost and Proximate composition of German grass

The manure had the following values: 5.9, 8.6, 2.65, 2.21, 1.83, and 1.25 for pH, organic carbon (%), nitrogen (%), phosphorus (mg 100 gm-1 manure), calcium (mg 100 gm-1 manure), and magnesium (mg 100 gm-1 manure), in that order. Sinha (2009) and Verma et al., (2012) found almost similar chemical composition of vermicompost. The percentage of moisture, ash, crude protein, crude lipid, crude fiber in German grass were 4.05, 10.57, 9.75, 3.40 and 35.57, respectively. Kanak et al., (2012) and Islam et al., (2017) observed 8.2 g crude protein, 34.4 g crude fiber and 10.9 g ash per 100 g DM in German grass. Close observation of feeding responses of the grass carp fingerlings is necessary to know the acceptability of the German grass.

Water quality parameters

Aquatic species depend heavily on the quality of their water for growth and survival. In aquaculture, good quality water supply is prerequisite for good production (Bisht et al., 2013). Throughout our research, various water quality indicators were assessed every two weeks' interval. Physical water quality parameter such as temperature (ºC) was measured every sampling day. Biological parameters such as phytoplankton density and zooplankton density (cells L^{-1}), and dissolved oxygen concentration, nitrite-nitrogen concentration, nitrate-nitrogen concentration, and phosphate-phosphorus concentration in mg L^{-1} were measured during water quality sampling.

Physical parameters

Water temperature (°C)

Aquatic production is significantly influenced by water temperature as it impacts the physical, chemical, and biological factors of a water body. Optimum temperature helps to obtain maximum aquatic production. Food intake, metabolisms and growth rate of fish increase with the increase of water temperature. The temperature of the water was found to range from 24.50 to 30.25, 24.35 to 30.30 and 24.60 to 30.35°C in treatments T_1, T_2 and T_3 respectively (Table 2). The mean of water temperature was 28.03 ± 0.27, 28.02 ± 0.21 and 28.13 ± 0.24°C in treatments T_1, T_2 and T_3, respectively. There were no noticeable differences. (p > 0.05) among the temperature recorded in different treatments. According to Bhatnagar et al., (2013), water temperatures between 28 and 35°C are ideal for fish farming. In the current investigation, it was discovered that water temperature was ideal for fish production, with mean values being roughly 28˚C in each treatment. The water temperature of the experimental ponds ranged from 24.35 to 30.35˚C during the experiment in three treatments which presented constancy with the findings of temperature ranged from 24.2 to 33.3˚C Kohinoor, (2000), 21.0 to 32.9˚C Hasan, (2007), 26.0 to 32.8˚C Hossain, (2007) and 26.9 to 32.0˚C Alam and Hossain, (2009).

Table 2. Mean (± SD) of water quality parameters measured in different treatments

Water parameters	Treatments			LSD	Level of significance
	T_1	T_2	T_3		
Water Temperature (ºC)	28.03 ± 0.27^a	28.02 ± 0.21^a	28.13 ± 0.24^a	0.45	NS
Transparency (cm)	29.72 ± 1.42^a	28.56 ± 0.66^{ab}	27.49 ± 1.98^b	2.17	*
DO (mg L^{-1})	7.80 ± 0.10^a	7.27 ± 0.17^b	7.37 ± 0.12^b	0.08	*
pH	6.80 ± 0.02^b	7.81 ± 0.05^a	8.03 ± 0.06^a	0.20	*
Nitrite-nitrogen (mg L^{-1})	0.06 ± 0.00^b	0.07 ± 0.01^a	0.08 ± 0.03^a	0.02	*
Nitrate-nitrogen (mg L^{-1})	0.32 ± 0.17^a	0.28 ± 0.08^a	0.25 ± 0.14^a	0.02	NS
Phosphate-phosphorus (mg L^{-1})	0.32 ± 0.02^c	0.82 ± 0.06^b	1.15 ± 0.02^a	0.26	*

LSD= Least Significant Difference

NS =Means are not significantly different (P>0.05)

*Means values with different superscript letters in the same row indicate significant difference at 5% significant level.

Chemical parameters

Dissolved oxygen (mgL^{-1})

One of the most important and crucial water quality criteria in aquaculture is the concentration of dissolved oxygen. The most important challenge in managing water quality is without a doubt maintaining optimal dissolved oxygen levels. Size, activity, food intake, dissolved oxygen concentration and water temperature are important variables that affect a fish's oxygen composition. Concentration of dissolved oxygen of water was observed ranging from 6.99 to 8.27, 7.67 to 7.74 and 6.60 to 7.85 mg L^{-1} in treatments T_1, T_2 and T_3, respectively. The mean of DO were 7.80 ± 0.10, 7.27 ± 0.17 and 7.37 ± 0.12 mg L^{-1} in treatments T_1, T_2 and T_3, respectively (Table 2). There were no significant differences ($p > 0.05$) recorded in treatments T_2 and T_3, but treatment T_1 showed significantly high ($p < 0.05$) DO. Boyd (1982) reported that optimum dissolved oxygen range for fish is 6.0 to 9.0 mg L^{-1}. The dissolved oxygen of the experimental ponds ranged from 7.0 to 8.0 mg L^{-1} during the experiment in three treatments which showed consistency with the findings of Boyd (1982), Chakrabarty et al., (2008) and Bisht et al., (2013) who reported dissolved oxygen ranges from 6.0 to 9.0, 6.01 to 7.74 and 5.7 to 8.0 mg L^{-1}, respectively

pH

The productivity index of a water body is regarded to be pH, which is also a significant element in fish culture. Growth rate, metabolic rate, and other physiological functions are all slowed down by an acidic pH (Rahman, 1992). pH was found to vary from 6.58 to 7.18, 7.72 to 8.00 and 7.76 to 8.45 in treatments T_1, T_2 and T_3, respectively. The mean values of pH were 6.80 ± 0.02, 7.81 ± 0.06 and 8.03 ± 0.06 in treatments T_1, T_2 and T_3, respectively (Table 2). pH of treatment T_1 is significantly different ($p < 0.05$) from that of treatments T_2 and T_3. According to Boyd and Pillai (1984) and Bhatnagar *et al.* (2013), suitable water pH for fish culture is ranged from 6.5 to 9.0. In the present study, concentration of pH was found to be favorable for fish culture. The relative comparison of mean of dissolved oxygen concentration between the feeding square and far from the feeding square at different treatments is listed in Table 3. The pH of the experimental ponds showed consistency with the findings of Hossain (2000), Alim (2005), Gupta et al., (2012) and Bisht et al., (2013) who found pH values ranges from 6.8 to 8.2, 6.2 to 8.9, 7.4 and 6.5 to 8.8, respectively.

Table 3. Relative comparison of mean (± SD) of dissolved oxygen concentration (mgL^{-1}) under the feeding square and far from feeding square at different treatments

Treatments	Dissolved oxygen (mg L^{-1}) under the feeding square	Dissolved oxygen (mg L^{-1}) far from the feeding square
T_1	7.2 ± 0.32	8.16 ± 0.64
T_2	6.9 ± 0.50	8.00 ± 0.38
T_3	6.9 ± 0.57	7.72 ± 0.56

Nitrite-nitrogen (mg L^{-1})

Because it turns the blood and gills brown and prevents breathing by oxidizing hemoglobin to methemoglobin, nitrite is sometimes referred to as a "unseen killer". Moreover, it effects fish's kidneys, spleen, liver, and neurological system. Nitrite-nitrogen, designated occurs in very minute quantities in unpolluted waters. During early winter, when nitrate concentration is low, nitrite content may increase. Nitrite-nitrogen (NO_2-N) concentrations of water was found to range from 0.04 to 0.10, 0.04 to 0.11 and 0.05 to 0.12 mg L^{-1} in treatments T_1, T_2 and T_3, respectively. The mean of nitrite-nitrogen was 0.06 ± 0.00, 0.07 ± 0.01 and 0.08 ± 0.03 mg L^{-1} in treatments T_1, T_2 and T_3, respectively (Table 2). Nitrite-nitrogen of treatment T_1 was significantly different ($p < 0.05$) from T_2 and T_3, although there were no significant differences ($p > 0.05$) between the nitrite-nitrogen values of treatments T_2 and T_3. According to Stone and Thomforde (2004), the nitrite-nitrogen range optimal for fish production is 0 to 1.0 mg L^{-1}. During the trial nitrite nitrogen concentration range was 0.04 to 0.12 mg L^{-1}in three treatments which showed consistency with the findings of Bisht et al., (2013) who found the nitrite-nitrogen ranges from 0.02 to 0.15 mg L^{-1}.

Nitrate-nitrogen (mg L^{-1})

In fresh water that are not polluted, nitrate-nitrogen (NO_3-N) often exists in relatively low concentrations. Nitrate-nitrogen concentration was ranging from 0.09 to 0.70, 0.06 to 0.75 and 0.10 to 0.55 mg L^{-1} in treatments T_1, T_2 and T_3, respectively. The mean of nitrate-nitrogen was 0.32 ± 0.17, 0.28 ± 0.08, and 0.25 ± 0.14 mg L^{-1} in treatments T_1, T_2 and T_3, respectively (Table 2). There was no significant difference ($p > 0.05$) among the nitrate-nitrogen recorded in different treatments. According to Santhosh and Singh (2007), pond water with a nitrate-nitrogen concentration of 0.1 to 4.0 mg L^{-1} is suitable for fish culture. The almost satisfactory results were obtained with nitrate-nitrogen concentrations ranging from 0.01 to 0.88 mg L^{-1} which supported by findings of Uddin, (2002); 0 to 0.70 mg L^{-1} Alim, (2005) and 0 to 0.45 mg L^{-1} Ferdous, (2007).

Phosphate-phosphorus (mg L^{-1})

An essential fertilizer for aquaculture ponds is phosphate. It is a major nutrient and essential for phytoplankton, the primary producer of water. Phosphate-phosphorus (PO_4-P) concentration was ranging from 0.22 to 0.48, 0.62 to 1.30, 0.75 to 1.83 mg

L^{-1} in treatments T_1, T_2 and T_3, respectively. The mean values of phosphate-phosphorus were 0.32 ± 0.02, 0.82 ± 0.06, 1.15 ± 0.02 mg L^{-1} in treatments T_1, T_2 and T_3, respectively (Table 2). Phosphate-phosphorus was found to vary significantly ($p < 0.05$) in all three treatments. Bhatnagar et al., (2013) found that the suitable range of phosphate-phosphorus in pond for fish culture ranged from 0.01 to 3.0 mg L^{-1}. The mean values of phosphate-phosphorus of this study showed consistency with the findings of Haque (2000) and Bisht et al., (2013) who found phosphate-phosphorus ranges from 0.35 to 2.51 and 0.36 to 2.38 mg L^{-1}, respectively.

Biological parameters

Phytoplankton (cells L^{-1})

29 taxa of phytoplankton from the experimental ponds were separated into four categories, including the Bacillariophyceae (9 species), Chlorophyceae (15 species), Cyanophyceae (3 species), and Euglenophyceae (2 species). In treatments T_1, T_2, and T_3, the similarly availability of phytoplankton was reported to range from 1.0×10^3 to 4.5×10^3, 4.5×10^3 to 9.0×10^3, and 5.0×10^3 to 11.5×10^3 cells L^{-1}, with mean values of 3.00±0.67 ($\times10^3$), 6.67±1.1 ($\times10^3$), and 8.33±1.8 8 ($\times 10^3$ cells L^{-1}), respectively. Bansal et al., (2014) observed more or less similar abundance 0.7×10^3 to 52×10^3 cells L^{-1} of phytoplankton.

Zooplankton (cells L^{-1})

The 9 genera of zooplankton, including species from the families Crustacea (7 species) and Rotifera (2 species), were detected in the trial ponds. By the same way concentration of zooplankton was observed to range from 0.5×10^3 to 2.5×10^3, 3.0×10^3 to 9.0×10^3 and 5.0×10^3 to 10.0×10^3 cells L^{-1} with mean of 1.00 ± 0.40 ($\times 10^3$), 5.33 ± 1.40 ($\times 10^3$) and 6.67 ± 0.90 ($\times 10^3$ cells L^{-1}) in treatments T_1, T_2 and T_3, respectively. Bansal et al., (2014) also observed higher abundance of zooplankton in ponds treated with different doses of vermicompost and ranged from 0.1×10^3 to 1.7×10^3 cells L^{-1}.

Gut content analysis

Phytoplankton species such as, *Anabaena* sp., *Euglena* sp., *Microspora* sp., *Phytoconis* sp., *Spirogyra* sp., *Sphaerocystis* sp., *Tabellaria* sp., *Ulothrix* sp., *Zygnema* sp. were commonly observed and *Gomphonema* sp., *Oscillatoria* sp., *Oogonium* sp., *Palmella* sp., *Volvox* sp. were rarely observed in the Grass carp gut (Table 4). Similarly, *Anabaena* sp., *Ankistrodesmus* sp., *Botryococcus* sp., *Cyclotella* sp., *Euglena* sp., *Microspora* sp., *Nitzschia* sp., *Phytoconis* sp., *Pinnularia* sp., *Synedra* sp., *Sphaerocystis* sp., *Ulothrix* sp., *Zygnema* sp. were commonly observed and *Chlorella* sp., *Closterium* sp., *Cocconesis* sp., *Navicula* sp., *Phacus* sp., *Surirella* sp. were rarely observed in the Nile tilapia gut (Table 4). It is now common practice to examine fish feeding behaviors using gut content analysis (Hyslop, 1980; Lagler, 1949). A quantitative evaluation of food intake and key insights into fish feeding patterns are provided by stomach content analysis. The meals of fish represent a combination of numerous significant ecological factors, including behavior, condition, habitat utilization, energy intake, and inter and intraspecific interactions.

Table 4. Gut contents of Grass carp and Nile tilapia in the experimental ponds

Species	Gut contents	Frequency
Grass carp	German grass	All
	Phytoplankton: *Anabaena* sp., *Euglena* sp., *Microspora* sp., *Phytoconis* sp., *Spirogyra* sp., *Sphaerocystis* sp., *Tabellaria* sp., *Ulothrix* sp., *Zygnema* sp.	C
	Phytoplankton: *Gomphonema* sp., *Oscillatoria* sp., *Oogonium* sp., *Palmella* sp., *Volvox* sp.	R
Nile tilapia	Phytoplankton: *Anabaena* sp., *Ankistrodesmus* sp., *Botryococcus* sp., *Cyclotella* sp., *Euglena* sp., *Microspora* sp., *Nitzschia* sp., *Phytoconis* sp., *Pinnularia* sp., *Synedra* sp., *Sphaerocystis* sp., *Ulothrix* sp., *Zygnema* sp.	C
	Phytoplankton: *Chlorella* sp., *Closterium* sp., *Cocconesis* sp., *Navicula* sp., *Phacus* sp., *Surirella* sp.	R
	Zooplankton: *Brachionus* sp., *Cyclops* sp., *Daphnia* sp., *Diaptomus* sp., *Diaphanosoma* sp., *Eubosmina* sp., *Filinia* sp.	C
	Zooplankton: *Moina* sp., Unidentified nauplius	R
	Detritus, grass carp feces	C
	German grass	R

C = commonly observed; R = rarely observed.

Growth response of fish

Growth performance of grass carp and tilapia

When stocking density is same in all treatments, grass carp and tilapia both performed well in terms of weight gain (T_1, T_2 and T_3) for a period of 77 days from 15 September to 07 December 2014 is presented in Fig. 1 and Fig. 2. Proper growth performance of grass carp and tilapia fingerlings are estimated in various treatment during experimental period, initial weight (g) of fingerlings, final weight (g), mean weight (g), mean weight gain (g fish^{-1}), percentage (%) weight gain, SGR (% per day) and survival (%) were estimated and presented in Table 5 and 6.

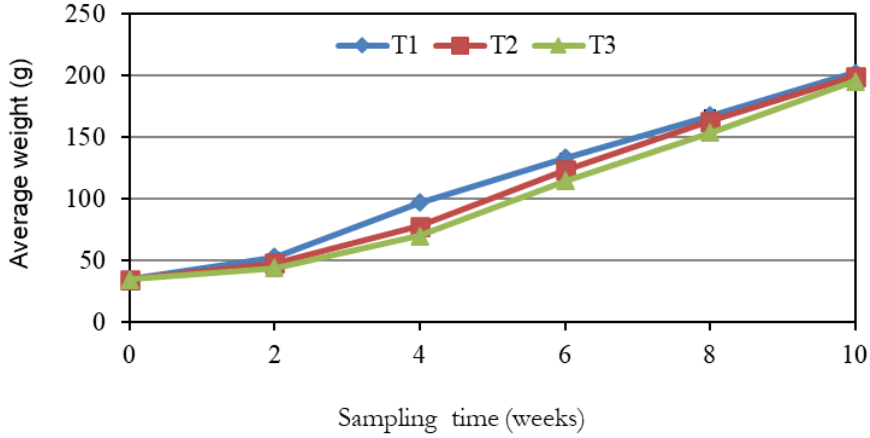

Figure 1. Average weight (g) of grass carp in various treatments during the experimental period.

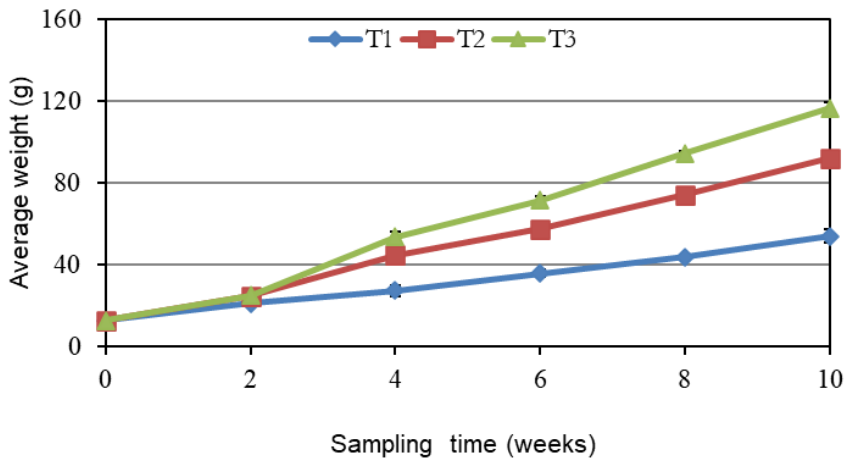

Figure 2. Average weight (g) of tilapia in different treatments during the experimental period.

Initial and final weight (g) of grass carp and tilapia

When they were first stocked, grass carp fingerlings weighed 34.91 grams and were 14.2 centimeters in length. The primary weight of fish in the various treatments weren't really different. ($p < 0.05$). The mean final weight of fish were 203.57 ± 2.56 in T_1, 200.20 ± 1.76 in T_2 and 197.83 ± 4.96 g in T_3 (Table 6). In contrast, the initial weight and length of tilapia fingerlings were 12.98 g and 8.5 cm when first stocked (Table 6). No significant ($p < 0.05$) variation was found in initial fish weight in various treatments (Table 5 and 6). The concluding mean fish weight was 52.97 ± 2.66, 91.10 ± 2.13 and 114.53 ± 4.15 g in treatments T_1, T_2 and T_3 respectively. In treatment T_3, where manuring was done with vermicompost with the dose of 16,000 kg vermicompost ha^{-1} year^{-1} and freshly chopped German grass was employed up to ad-libitum, the largest final weight (114.53 g) was noticed. The minimum final weight (52.97 g) was observed in treatment T_1, where only freshly chopped German grass was used (Table 6).

Table 5. Stocking and harvesting size, mean weight gain, percentage weight gain, survival, SGR and production of grass carp in different treatments

Items	Treatments			LSD	Level of significance
	T_1	T_2	T_3		
Initial mean weight (g fish^{-1})	34.91 ± 19.65^a	34.91 ± 19.65^a	34.91 ± 19.65^a	0.00	NS
Final mean weight (g fish^{-1})	203.57 ± 2.56^a	200.20 ± 1.76^a	197.83 ± 4.96^a	5.28	NS
Mean weight gain (g fish^{-1})	168.66 ± 2.56^a	165.29 ± 5.28^a	162.92 ± 4.06^a	5.28	NS
% Weight gain	483.12 ± 7.33^a	473.47 ± 5.03^a	466.70 ± 11.62^a	15.11	NS
Survival rate (%)	83.00 ± 1.73^a	82.67 ± 1.15^a	80.67 ± 1.73^a	1.19	NS
SGR (% wt. gain day^{-1})	2.35 ± 0.02^a	2.33 ± 0.01^a	2.31 ± 0.03^a	0.04	NS

Production (ton ha^{-1} 77 $days^{-1}$)	1.63 ± 0.04^a	1.51 ± 0.03^a	1.30 ± 0.04^a	0.02	NS

LSD= Least Significant Difference; NS =Means are not significantly different ($p > 0.05$)

*Means values with different superscript letters in the same row indicate significant difference at 5% significant level.

Table 6. Stocking and harvesting size, mean weight gain, percentage weight gain, survival rate, SGR and production of tilapia in different treatments

Items	Treatments			LSD	Level of significance
	T_1	T_2	T_3		
Initial mean weight (g $fish^{-1}$)	12.98 ± 5.25^a	12.98 ± 5.25^a	12.98 ± 5.25^a	0.00	NS
Final mean weight (g $fish^{-1}$)	52.97 ± 2.66^c	91.10 ± 2.13^b	114.53 ± 4.15^a	4.39	*
Mean weight gain (g $fish^{-1}$)	39.99 ± 2.66^c	78.12 ± 2.13^b	101.55 ± 4.15^a	4.39	*
% Weight gain	308.06 ± 20.48^c	601.85 ± 16.40^b	782.38 ± 31.99^a	33.81	*
Survival rate (%)	84.00 ± 1.00^c	87.67 ± 0.58^b	90.00 ± 1.00^a	1.19	*
SGR (% wt. gain day^{-1})	1.87 ± 0.07^c	2.60 ± 0.03^b	2.90 ± 0.05^a	0.08	*
Production (ton ha^{-1} 77 $days^{-1}$)	0.94 ± 0.05^c	1.27 ± 0.03^b	1.64 ± 0.03^a	0.02	*

LSD= Least Significant Difference; NS =Means are not significantly different ($p > 0.05$)

*Means values with different superscript letters in the same row indicate significant difference at 5% significant level.

Weight gain (g) of grass carp and tilapia

The mean weight gain of grass carp were 168.66 ± 2.56, 165.29 ± 5.28 and 162.92 ± 4.06 g in treatments T_1, T_2 and T_3, respectively. There was no noticeable difference ($p < 0.05$) in the mean weight gain of fish in various treatments (Table 5 and 6). On the other hand, the mean weight gain of tilapia were 39.99 ± 2.66 g in treatment T_1, 78.12 ± 2.13 g in treatment T_2 and 101.55 ± 4.15 g in treatment T_3 (Table 6). The treatment T_3 where vermicompost was given 16,000 kg ha^{-1} $year^{-1}$ rate of dose with German grass showed the highly significant ($p < 0.01$) weight gain (101.55 g). Treatment T_1, which used simply German grass, had the lowest weight gain (39.99 g) (Table 5 and 6).

Percentage weight gain (%) of grass carp and tilapia

The mean percent weight gain of grass carp were 483.12 ± 7.33, 473.47 ± 5.03 and 466.70 ± 11.62 for treatments T_1, T_2 and T_3 respectively (Table 6). There was no noticeable difference ($p < 0.05$) in the percentage weight gain of fish among various treatments (Table 5 and 6). In contrast, the mean (± SD) percent weight gain of tilapia were 308.06 ± 20.48, 601.85 ± 16.40 and 782.38 ± 31.99% in treatments T_1, T_2 and T_3, respectively. In treatment T_3, where vermicompost provided at 16,000 kg ha^{-1} $year^{-1}$ dose and German grass was applied, the weight gain percentage (782.38%) was seen which is remarkably significant ($p < 0.01$). The lowest weight gain percentage (782.38%) was found in treatment T_1, where using only German grass (Table 5 and 6).

Specific growth rate (SGR% wt. gain day^{-1}) of grass carp and tilapia

The average (± SD) specific growth rate of grass carp were 2.35 ± 0.02, 2.33 ± 0.01 and 2.31 ± 0.03% day^{-1} in treatments T_1, T_2 and T_3, respectively (Table 5 and 6). There were no significant differences ($p > 0.05$) in the specific growth rate of fish among three treatments. The specific growth rate of grass carp belonging to treatments T_1 (2.35), T_2 (2.33) and T_3 (2.31% day^{-1}) are shown in Table 6. On the other hand, the average values of particular growth rate of tilapia were 1.87 ± 0.07, 2.60 ± 0.03 and 2.90 ± 0.05% day^{-1} in treatment T_1, T_2 and T_3, respectively. There was highly significant ($p < 0.01$) differences in SGR among the different treatments (Table 5 and 6). SGR progressively increased with the increasing dose of vermicompost from treatment T_2 to T_3. The highest significant specific growth rate (2.90% day^{-1}) was estimated in treatment T_3. In contrast, the lowest specific growth rate (1.87% day^{-1}) (Table 6).

Survival rate (%) of grass carp and tilapia

The average survival rate of grass carp were 83.00 ± 1.73, 82.67 ± 1.15 and 80 ± 1.73% in treatments T_1, T_2 and T_3 respectively (Table 5 and 6). There were no significant differences ($p > 0.05$) in the survival rate of fish among various treatments. Pandit et al., (2003) found survival rate of grass carp ranges from 80.6 to 91.7% when napier grass was used as the sole nutrient input for the polyculture of grass carp and tilapia. The findings of Pandit et al., (2003) are more or less consistent with the present study. The mean survival rate of grass carp under treatments T_1 (83), T_2 (82.67) and T_3 (80%) are presented in Table 6. In contrast, the mean survival rate of tilapia was 84.00 ± 1.00 in treatment T_1, 87.67 ± 0.5 in treatment T_2 and 90.00 ± 1.00% in treatment T_3. On the contrary, the lowest survivability was observed in treatment T_3 (Table 5 and 6). Pandit et al., (2003) found 100% survival rate of tilapia using napier grass as the sole nutrient input for the polyculture of grass carp and tilapia are consistent with the present study.

Production of grass carp and tilapia

The gross production of grass carp and tilapia was 2.57±0.10 in treatment T_1, followed by 2.78 ± 0.22 in treatment T_2 and 2.94 ± 0.13 Ton ha^{-1} 77 $days^{-1}$ in treatment T_3 (Table 5 and 6). The gross production of treatments T_2 and T_3 were found to be significantly higher ($p < 0.05$) than treatment T_1. Pond productivity in manured ponds was notably ($p < 0.05$) higher than in control ponds. Hence, vermicompost with German grass can be used more effectively for grass carp and tilapia culture without affecting the physico-chemical parameters. The growth of tilapia was considerably better in treatment T_3 This might be because vermicompost contains more nutrients, specifically more nitrogen, phosphate, and potassium. In comparison to conventionally applied organic and inorganic fertilizers, vermicompost-treated ponds showed more plankton production (Chakrabarty et al., 2008 and 2010; Kumar et al., 2012; Bansal et al., 2014). Kumar et al., (2005) obtained the highest net fish production of 5.6 Ton ha^{-1} in grass carp with organic fertilizer treatment rather than only inorganic fertilizer treatment with a production of 3.0 Ton ha^{-1}. Chakrabarty et al., (2010) obtained a production of 4.0 Ton ha^{-1} 90 $days^{-1}$ of *Oreochromis mossambicus* culture using vermicompost. Guererro and Guerrero (2014) found a production of 139.6 kg ha^{-1} 120 $days^{-1}$ at vermicompost dose of 2.5 Ton ha^{-1} and 48.4 kg ha^{-1} 120 $days^{-1}$ at vermicompost dose of 5 Ton ha^{-1} for tilapia culture in freshwater ponds.

Economic analysis

Cost and returns were determined on the basis of production. Various inputs were used in managing the culture ponds. Total cost of pond preparation was 24,700 BDT ha^{-1}. Liming was done at the rate of 1.0 kg $decimal^{-1}$ during preparation of pond for fish culture. The cost of lime was 16 Taka kg^{-1}. So, total cost of lime was 3952 BDT ha^{-1}. Total dose of vermicompost used in treatment T_2 and T_3 was 178.2 kg and the cost of vermicompost was 10 Taka kg^{-1}. Total cost of vermicompost was 25,097 BDT ha^{-1}. Total cost for German grass production was 57,633 BDT ha^{-1}. No lease value was needed for the lands used for German grass production. Total fingerling cost was 20,7480 BDT ha^{-1}. Total transport cost was 27,417 BDT ha^{-1}. Total cost of harvesting was 15,067 BDT ha^{-1}. Total input cost was 3,36,249; 3,52,551 and 3,68,853 BDT ha^{-1} in treatments T_1, T_2 and T_3, respectively. On the other hand, net returns were estimated based on the total revenue of the grass carp and tilapia fish that were obtained from the ponds following treatments T_1, T_2, and T_3, consecutively. The selling price of both grass carp and tilapia was 140 Taka kg^{-1}. In the present study, gross return was 18,029; 36,075 and 42,162 BDT ha^{-1} in treatments T_1, T_2 and T_3, respectively.

Net income

Net income was 18,029; 36,075 and 42,162 BDT ha^{-1} in treatments T_1, T_2 and T_3, respectively. Both the gross income and net income were significantly higher in treatments T_2 and T_3 than treatment T_1. In this study, the highest net income 42,162 BDT ha^{-1} in 77 $days^{-1}$ came from treatment T_3. The net market price of both grass carp and tilapia was considered as BDT 140 kg^{-1}. Thus, the present study suggests that utilizing vermicompost with German grass in T_3 has a larger chance of raising the net income from grass carp and tilapia polyculture and supporting fish farmers financially and nutrient-wise.

Conclusion

Sustainable aquaculture depends upon eco-friendly, economically and socially viable culture system. By lowering spending on overpriced feeds and inorganic fertilizers, which make up more than half of the overall input expenses, vermicompost and German grass use in fish ponds may be crucial for sustainable aquaculture. It was observed that the water quality parameters (physical, chemical and biological) were within the suitable range for fish culture during the study period. The gut content analysis showed that grass carp consumed both German grass and phytoplankton. In contrast, tilapia consumed mainly phytoplankton and zooplankton along with German grass and feces of grass carp. Therefore, German grass may have a potential contribution in grass carp and tilapia polyculture. Fish feed and chemical fertilizers are expensive to small-scale, resource-poor subsistence farmers. On the other hand, the surrounding freshwater and marine aquatic environments are being contaminated by the use of chemicals, antibiotics, and farmed fish feed. The results of this study will support decreased input costs, the conservation of finite resources, high-value markets for organic fish products, and an increase in the farmers' income. Thus the farmers will be benefited and their socio-economic condition will be upgraded as well as producing organic fish will maintain ecologically-friendly environment.

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Conflict of interest

The author declares no conflict of interest.

Data availability statement

The data that support the findings of this study are available on a reasonable request from the corresponding author.

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