Minimizing feed ration of *Oreochromis niloticus* in pond culture using vermicompost

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Abstract. The main objective of the present study was to minimize the feed ration of *Oreochromis niloticus* in pond culture using vermicompost. The experiment was carried out in field laboratory ponds of Faculty of Fisheries, BSMRAU, for 105 days from May to September 2018. There was a total of four treatments. Treatment T_1 was used as a control with only commercial fish feed at 2% of body weight, while vermicompost was used in three treatments at different dosses with fish feed at the same percentage of body weight. Manuring was done with vermicompost at a dose 8,000 kg ha^{-1} $year^{-1}$, 16,000 kg ha^{-1} $year^{-1}$ and 24,000 kg ha^{-1} $year^{-1}$ in treatments T_2, T_3 and T_4, respectively. Out of total dose, 25% was applied 15 days before stocking of fish and rest in equal weekly installments after stocking of fish. There were 18 genera of phytoplankton and nine genera of zooplankton identified in all four treatments. The mean abundance of both phytoplankton and zooplankton was found to show a significant difference ($P<0.05$) among the treatments. The recorded gross production was significantly higher in treatment T_4 (5.55 ton ha^{-1} 105 $days^{-1}$) followed by T_3 (4.86 ton ha^{-1} 105 $days^{-1}$), T_2 (4.73 ton ha^{-1} 105 $days^{-1}$) and T_1 (3.44 ton ha^{-1} 105 $days^{-1}$). The study revealed that the application of vermicompost at a dose of 24,000 kg ha^{-1} $year^{-1}$ at 2% of body weight of feed was cost-effective for tilapia (*O. niloticus*) culture in ponds through minimizing feed ration. The used doses of vermicompost particularly T_4 enhanced the production of tilapia in contrast with the traditional feeding (5% of body weight). This dose of vermicompost saved 3% feeding cost, which enhances the net income of fish farmers.

Key Words: monosex tilapia, fertilization, earthworms, body weight, feeding cost.

Introduction. Bangladesh is one of the world's leading fish producing countries with a total production of 4.27 million MT in FY 2017-18, where aquaculture production contributes 56.24% of the total fish production. Aquaculture shows consistent and robust growth; the average growth rate is almost 10% during the same timeframe. Bangladesh is ranked 3^{rd} in inland open water capture production and 5^{th} in world aquaculture production based on the FAO report (FAO 2018).

Currently, Bangladesh ranks 4^{th} in tilapia production in the world and 3^{rd} in Asia (DoF 18). But the sustainability of aquaculture production is now facing some challenges. In Bangladesh, one of the major costs of fish farming is the feeding cost which comprises of 70-79% of the total cost. Due to overfeeding and high feed conversion ratio (FCR) the farmers have to pay some unnecessary costs. One of the key reasons for fish culture on a small-scale basis is futile because of inadequate information about optimum stocking density and feeding regime (Reza 2013). Nile tilapia (*Oreochromis niloticus*) commercially known as nilotica is a widely cultured and economically important fish species because it grows in a wide range of environmental conditions and tolerates stress induced by handling (Edwards 2000; Ispir et al 2011).

Monosex tilapia culture is getting popular among farmers for its high growth rate along with its easier management pattern. Farmers choose single-sex which displays marked growth superiority (Reza 2013). This culture strategy of tilapia substantiates its efficacy to induce a progress towards tilapia culture in Bangladesh.

The profitability of fish farming depends, to a large extent, on the amount of supplementary feed used (Hepher & Pruginin 1981). It is important to minimize feed costs through the use of newer and cheaper sources of feed ingredients. Feed ingredients selection is one of the most important works that determine the cost and production of fish. So, it is imperative to find an alternative source for fish production, which will reduce feeding costs as well as economically and environmentally viable. In this regard, vermicompost could be the best option to reduces the risk of harmful effects of chemical fertilizer. Therefore, application of vermicompost to fish ponds control the impact of pollution of soil and water, and gives the better healthy ecosystem in cultivable pond ensuring better survivability and growth of cultured fishes (Bhuyan 2010).

Previous research suggested that the use of vermicompost has no deleterious effect on the hydrological characteristics and productivity profile of the cultivable pond (Ovie & Adenji 1991). The application of vermicompost as organic manure is utile to produce a sufficient quantity of zooplankton for nursery fish pond management (Ovie & Adenji 1991). However, there is lack of available information on using vermicompost as organic manure on water quality regimes and fish production. The vermicompost is a high grade fertilizer with nutrient values of 2.5-3.0% nitrogen, 1.8-2.9% phosphorus and 1.4-2.0% potassium, while cow dung contain 0.4-1.0% nitrogen, 0.4-0.8% phosphorus and 0.8-1.2% potassium (Sinha 2009; Verma et al 2012). In fish and prawn culture, vermicompost have been reported to result in higher survival and growth rate (Kumar et al 2007) without deteriorating the water quality. Moreover different research has been already reported that remarkably higher plankton production as well as fish growth (common carp, *Cyprinus carpio*) found in vermicompost treated ponds rather than traditionally used organic manures and inorganic fertilizers (Chakrabarty et al 2008, 2009). Though vermicompost has already used in other countries and got promising results, it is new in Bangladesh as well as the species tilapia.

The aim of the present study was to determine the efficacy of vermicompost on water quality and growth performance of tilapia.

Material and Method

Experimental site and description of the ponds. An experiment was carried out in the pond complex (six ponds; average area 0.012±0.001 ha and depth 0.15±0.04 m) of Faculty of Fisheries, Bangabandhu Sheikh Mujibur Rahman Agricultural University, Gazipur, Bangladesh. The experiment was conducted for 15 weeks, from 20 May to 02 September 2018.

Preparation of vermicompost. Vermicompost was prepared from cow dung using earthworms. Earthworms consume biomass and excrete it in the digested form called worm casts. *Eisenia foetida* (red earthworm) was chosen because for its high multiplication rate and thereby converts the organic matter into vermicompost within 50–60 days. The following steps were followed for vermicompost preparation (Bansal & Kapoor 2000): At first, vermicomposting unit were kept in a cool, moist and shady site where size of vermicomposting bed was 18 × 4 × 1 feet. Then, cow dung was kept for partial decomposition for 15–20 days. At the bottom of the bed a layer of 15-20 cm of chopped dried grasses was kept as a bedding material. Then, red earthworm (1,500-2,000 individuals) was released on the upper layer of the bed. After releasing red earthworms, water was sprinkled three days interval to maintain adequate moisture and body temperature of the worms. Hood opening of the unit was exposed to sunlight in every 15 days for maintaining aeration and proper decomposition. Compost became ready within 50-60 days and was stored after drying. For the experiment vermicompost was used in the three treatments (T_2, T_3 and T_4). The composition of vermicompost is presented in Table 1.

Table 1

Compositions of the experimental vermicompost (dry matter basis)

Parameters	*Amounts*
pH	5.9
Organic carbon (%)	8.76
Nitrogen (%)	2.65
Phosphorous (mg 100 g^{-1} manure)	2.21
Calcium (mg 100 g^{-1} manure)	1.83
Magnesium (mg 100 g^{-1} manure)	1.25

Design of experiment. The experiment was carried out for a period of 15 weeks from May to September 2018. Ponds were randomly selected for 4 treatments, each with 2 replications. Treatment T_1 (F_o) was used as control with the only commercial fish feed of 2% body weight. Vermicompost were used in other three treatments at different dosses with fish feed of 2% body weight. Manuring were done with vermicompost at a dose 8,000 kg ha^{-1} $year^{-1}$, 16,000 kg ha^{-1} $year^{-1}$ and 24,000 kg ha^{-1} $year^{-1}$ in the T_2 (VC_8), T_3 (VC_{16}) and T_4 (VC_{24}) treatments, respectively. Out of the total dose of vermicompost, 25% was applied 15 days before stocking of fish and rest in equal weekly installments after stocking of fish (Table 2).

Table 2

Manuring schedule (per 0.012 ha) in different treatments

Treatments	*Dose of manure*		
	Total dose (kg)	*Initial dose (kg)*	*Weekly dose (kg)*
T_1	-	-	-
T_2	27.7	6.9	1.4
T_3	55.8	13.9	2.8
T_4	83.8	20.9	4.2

Fish stocking. The fingerlings of *O. niloticus* were stocked in early May 2018. Before stocking, all fishes were kept in a temporary small cage for conditioning, and the length and weight of fingerlings were recorded. The stocking rate of tilapia was 43,500 ind ha^{-1}. The average weight and length were about 10-15 g and 8-10 cm during stocking, respectively.

Feeding and fertilization. The experimental ponds were inspected twice every day, especially in the morning and in the afternoon to observe any abrupt changes in the environmental condition, the behavior of fishes and color of water. For the experiment, commercial fish feed was used for feeding the fish at the rate of 2% body weight daily. Feeds were applied twice a day, half in the morning and the rest in the afternoon. Feeding rates were adjusted according to increase of fish body weight observed after fortnightly sampling. The proximate composition of the experimental diet labeled by the manufacturer is presented in Table 3. No inorganic fertilizer was used in the experiment.

Table 3

Proximate compositions of the experimental feed labeled by the manufacturer (% dry matter basis)

Parameters	*Amounts (%)*
Moisture (maximum)	12
Protein (minimum)	30
Fat (minimum)	3
Crude fiber (maximum)	10
Ash (maximum)	14

Plankton identification and calculation. Both phytoplankton and zooplankton counting was performed with the help of Sedgwick-Rafter Counting Cell (S-R cell). Identification of both phytoplankton and zooplankton up to generic level was done according to Pennak (1953), Prcscott (1962), Needham & Needham (1963), Belcher & Swale (1978). The plankton population was determined using the formula of Rahman et al (2008):

$$N = \frac{A \times C}{L} \times 100$$

Where:
N = Number of plankton cells per liter of original water
A= Total number of plankton counted
C = Volume of final concentrated sample in mL
L = Volume of original water in liter
For each pond, mean number of plankton recorded was expressed numerically in per liter of water.

Growth parameters. Fishes were sampled fortnightly by using a cast net. Weight and length were measured by using a portable balance a centimeter-scale, respectively. All the fishes were collected at the end of the experiment. Then the final growth gained by the fishes was recorded by measuring the weight (g) of fish. The survival rate of fish for each treatment and replication was estimated on the basis of the number of fish harvested at the end of the experiment. By multiplying the average gain in weight of fish in gross by the total number of fish survived in each treatment the gross yield of fish for each treatment was determined. The growth performance of fish in different treatments was measured by using the following formula (Brown 1957):

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

$$\text{Weight gain (g)} = \text{Final body weight (g)} - \text{Initial body weight (g)}$$

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

$$\text{Specific growth rate (\% per day)} = \frac{\ln \text{final body weight(g)} - \ln \text{initial body weight(g)}}{\text{Culture period (days)}} \times 100$$

$$\text{Gross Production (ton/ha/15 weeks)} = \frac{\text{Gross weight(kg)of fish}}{1000}$$

Results and Discussion

Water quality parameters. Pond manuring is an essential step to increase pond productivity. Water quality is one of the most important factors affecting successful pond fish culture (Diana et al 1997). If water quality is excellent, then survival, growth, and production can achieve high values. Water quality parameters of the four treatments is presented in Table 4. Various physical and chemical water quality parameters were recorded fortnightly. One-way analysis of variance (ANOVA) was performed to measure whether any significant difference exists in the mean values of water quality parameters among different treatments.

The growth, food intake, reproduction, and other biological activities of aquatic organisms are largely influenced by water temperature. Therefore water temperature was monitored regularly, and no significant difference in temperature was found among different treatments.

Table 4

Mean (±SD) values of water quality parameters recorded from different treatments

Water parameters	*Treatments*				*LSD*	*Level of significance*
	T_1	T_2	T_3	T_4		
Water temperature (°C)	29.46±1.95[a]	29.59±1.99[a]	29.55±2.06[a]	29.40±2.04[a]	0.31	NS
Transparency (cm)	32.77±1.29[a]	29.46±2.17[b]	27.95±1.79[bc]	27.28±1.43[c]	1.39	*
DO (mg L^{-1})	8.0±1.81[a]	7.05±1.33[a]	7.51±1.67[a]	7.35±1.95[a]	1.78	NS
pH	7.33±0.89[a]	6.72±0.72[b]	6.88±0.62[ab]	6.82±0.67[ab]	0.53	*
Total alkalinity (mg L^{-1})	64.44±4.07[b]	73.37±5.80[ab]	78.62±6.16[a]	81.87±8.01[a]	12.34	*
Ammonia-nitrogen (mg L^{-1})	0.37±0.36[a]	0.44±0.43[a]	0.41±0.40[a]	0.32±0.32[a]	0.16	NS
Phytoplankton ($\times 10^3$ ind. L^{-1})	48.56±3.84[b]	52.31±5.40[bc]	53.50±5.66[b]	60.81±9.46[a]	4.02	*
Zooplankton ($\times 10^3$ ind. L^{-1})	3.12±1.16[c]	6.31±1.58[ab]	7.37±1.51[a]	9.44±2.18[a]	3.53	*

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% significance level.

Gross measure of pond productivity is simply expressed as water transparency. It has an inverse relationship with the abundance of plankton. Secchi disk reading is lower when phytoplankton density increased, which is an indication of the productivity of the water body. Secchi disc ranging from 20 to 30 cm indicates that the water body is productive if it is not turbid due to soil particles. The transparency was found to vary from 30.31 to 34.75 cm, 27.20 to 32.57 cm, 26.70 to 29.71 cm and 26.01 to 28.66 cm in T_1, T_2, T_3 and T_4 treatments, respectively. The mean (±SD) values of transparency were 32.77±1.29 cm, 29.46±2.17 cm, 27.95±1.79 and 27.28±1.43 cm in T_1, T_2, T_3 and T_4 treatments, respectively. The values of transparency were significantly different ($P<0.05$).

Dissolved oxygen concentration is one of the vital waters qualities parameters in aquaculture. The most crucial task of water quality management performed by fish culturists are maintenance of sufficient dissolved oxygen in ponds at all times. The amount of oxygen required by the aquatic animal is variable and depends primarily upon the size, food intake, activity, water temperature, and dissolved oxygen concentration. Dissolved oxygen (DO) concentration was found to vary from 4.55 to 10.65 mg L^{-1}, 4.75 to 8.50 mg L^{-1}, 4.50 to 9.20 mg L^{-1}, and 4.45 to 10.10 mg L^{-1} in T_1, T_2, $T_{3,}$ and T_4 treatments, respectively. The mean (±SD) values of DO were 8.0±1.81 mg L^{-1}, 7.05±1.33 mg L^{-1}, 7.51±1.67 mg L^{-1} and 7.35±1.95 mg L^{-1} in T_1, T_2, T_3 and T_4 treatments, respectively. According to DoF (2018) the range of dissolved oxygen level that is suitable for fish culture is 5.0 to 8.0 mg L^{-1} and the data of this experiment support this too.

pH level of cultured water is another important issue in fish culture and considered as one of the imperative factor that regulates the productivity of a water body. Water with pH value from 6.5 to 9 is considered best for fish production. An acidic pH reduces the growth rate, metabolic rate, and other physiological activities of fishes (Rahman et al 1992). pH concentration was found to vary from 6.27 to 9.15, 6.08 to 7.70, 6.16 to 7.73, and 6.16 to 7.76 in T_1, T_2, T_3 and T_4 treatments, respectively. The mean values of pH were 7.33±0.89, 6.72±0.72, 6.88±0.62 and 6.82±0.67 in T_1, T_2, T_3 and T_4 treatments, respectively. The difference among treatment was significant ($P>0.05$). In this experiment the lowest pH value found in treatment T_4. Due to continuous accumulation of vermicompost, the pH of water may decrease in the last half of the experimental period in all treatment except control. The pH value (6.16 to 9.15) recorded from the experimental pond showed consistency with the findings of pH values ranged from 6.4 to 9.0 (Hasan 2007), 7.72 to 8.30 (Alam 2009), 7.74-9.45 (Akter 2012) and 6.98 to 8.3 (Reza 2013) in fish culture ponds.

If the alkalinity is 40 mg L^{-1} or higher in a pond then that will be more productive compared with pond having lower alkalinity (Mairs 1966). Total alkalinity of water was ranged from 62 to 69 mg L^{-1}, 64 to 80 mg L^{-1}, 67 to 85 mg $L^{-1,}$ and 67 to 87 mg L^{-1} in T_1, T_2, $T_{3,}$ and T_4 treatments, respectively. The mean (±SD) values of total alkalinity were 64.44±4.07 mg L^{-1}, 73.37±5.80 mg L^{-1}, 78.62±6.16 mg L^{-1} and 81.87±8.01 mg L^{-1} in T_1, T_2, $T_{3,}$ and T_4 treatments, respectively.

Ammonia-nitrogen (NH_4-N) concentration in water of the experimental ponds was found to vary from 0.3 to 0.45 mg L^{-1}, 0.35 to 0.5 mg L^{-1}, 0.35 to 0.5 mg L^{-1} and 0.25 to 0.45 mg L^{-1} in T_1, T_2, T_3 and T_4 treatments, respectively. The mean (±SD) values of ammonia-nitrogen (NH_4-N) were 0.37±0.36 mg L^{-1}, 0.44±0.43 mg L^{-1}, 0.41±0.40 mg L^{-1} and 0.32±0.32 mg L^{-1} in T_1, T_2, T_3 and T_4 treatments, respectively. There was no significant ($P>0.05$) difference between the four treatments. Chen (1988) found that lower than 1 mg L^{-1} ammonia-nitrogen content in the pond was good for fish culture. The mean values of ammonia-nitrogen (NH_4-N) of the present study were similar to Akter (2012), and Asadujjaman (2012) recorded ammonical-nitrogen value ranged from 0.01 to 0.82, 0.22 to 0.60 and 0.001 to 0.55 mg L^{-1} respectively. The ammonical-nitrogen value of the present study was within the suitable range for tilapia culture.

Phytoplankton composition. A total of 18 genera of phytoplankton belonging to different groups of Bacillariophyceae, Chlorophyceae, Cyanophyceae, and Euglenophyceae were found in the experimental ponds (Table 5). The fortnightly abundance of phytoplankton was found to range from 43.0 to 53.5, 43.5 to 59.5, 47.0 to 62.0 and 47.5 to 68.0 ($\times 10^3$ cells L^{-1}) with mean (±SD) values of 48.56±3.84, 52.31±5.40, 53.50±5.66 and

60.81±9.46 (× 10^3 individuals L^{-1}) in T_1, T_2, T_3, and T_4 treatments, respectively. The highest abundance of total phytoplankton was found in treatment T_4 and followed by T_3, T_2, and T_1. There was significant ($P<0.05$) difference among treatments T_1, T_2, T_3, and T_4 (Table 4 and 6). Fortnightly variations of total phytoplankton in the four treatments are shown in Figure 1. The maximum phytoplankton genera and abundance were found in treatment T_4, where the highest amount of vermicompost was applied and did not adversely affect the water quality parameters. The lowest phytoplankton was found in T_1, where only feed used.

Table 5

The generic status of phytoplankton and zooplankton found in the experimental ponds

Phytoplankton		*Zooplankton*
Bacillariophyceae *Cyclotella* *Navicula* *Nitzschia* *Surirella* *Synedra* *Tabellaria* **Chlorophyceae** *Ankistrodesmus* *Chlorella* *Closterium* *Coelastrum* *Scenedesmus* *Spirogyra* *Tetrahedron* *Ulothrix* *Volvox* *Zygnema*	**Cyanophyceae** *Oscillatoria* **Euglenophyceae** *Euglena*	**Crustacea** *Daphnia* *Diaphanosoma* *Moina* *Cyclops* *Diaptomus* **Rotifera** *Asplanchna* *Brachionus* *Filinia* *Keratella*

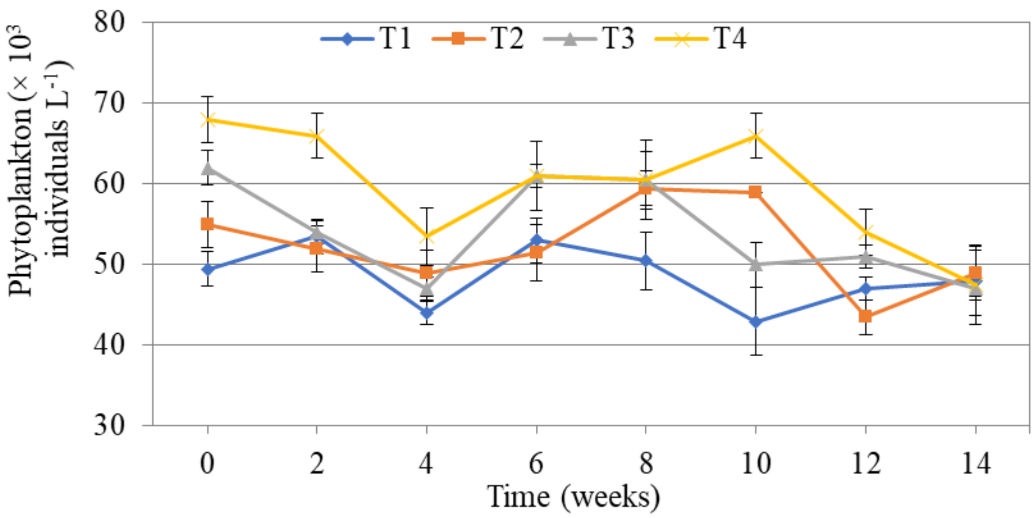

Figure 1. The fortnightly fluctuation of phytoplankton among four treatments.

Zooplankton composition. A total of 9 genera of zooplankton belonging to two groups of Crustacea and Rotifera were found in the experimental ponds during the experimental period (Table 5). The fortnightly abundance of zooplankton was found to range from 2.0 to 5.5, 3.5 to 9.6, 4.5 to 9.5 and 5.5 to 13.0 (× 10^3 individuals L^{-1}) with mean values of 3.12±1.16, 6.31±1.58, 7.37±1.51 and 9.44±2.18 (× 10^3 individuals L^{-1}) in T_1, T_2, T_3, and T_4 treatments, respectively. The highest abundance of total zooplankton was found in treatment T_4 and followed by T_3, T_2, and T_1. There was a significant ($P<0.05$) difference among treatments T_1, T_2, T_3, and T_4 (Table 6). Fortnightly variations of total zooplankton in four treatments are shown in Figure 2.

Table 6

Mean abundance ($\times 10^3$ individuals L^{-1}) of plankton recorded from the ponds under four treatments

Variables	*Treatments*				*LSD*	*Level of significance*
	T_1	T_2	T_3	T_4		
Bacillariophyceae	19.65 ± 5.78^a	8.94 ± 3.74^a	10.27 ± 4.32^a	11.78 ± 5.67^a	22.52	NS
Chlorophyceae	19.48 ± 7.03^b	30.91 ± 13.37^{ab}	29.63 ± 15.38^{ab}	38.5 ± 10.62^a	16.05	*
Cyanophyceae	6.54 ± 2.54^a	7.52 ± 3.54^a	6.04 ± 3.45^a	4.43 ± 2.37^a	7.68	NS
Euglenophyceae	2.89 ± 3.64^a	4.93 ± 2.38^a	7.55 ± 1.97^a	6.09 ± 3.85^a	8.85	NS
Total phytoplankton	48.56 ± 3.84^b	52.31 ± 5.40^{bc}	53.5 ± 5.66^b	60.81 ± 9.46^a	4.02	*
Rotifera	0.92 ± 0.56^b	2.04 ± 1.21^{ab}	2.82 ± 1.34^a	3.47 ± 2.02^a	1.83^a	NS
Crustacea	2.20 ± 1.72^a	4.26 ± 2.43^a	4.55 ± 2.46^a	5.97 ± 2.89^a	5.20	NS
Total zooplankton	3.12 ± 1.16^c	6.31 ± 1.58^{ab}	7.37 ± 1.51^a	9.44 ± 2.18^a	3.53	*
Total plankton	51.68 ± 5.35^c	58.62 ± 4.02^b	60.87 ± 8.14^b	70.25 ± 6.32^a	6.83	*

NS - Means are not significantly different (P>0.05), * Mean values with different superscript letters in the same row indicate significant difference at 5 % significance level.

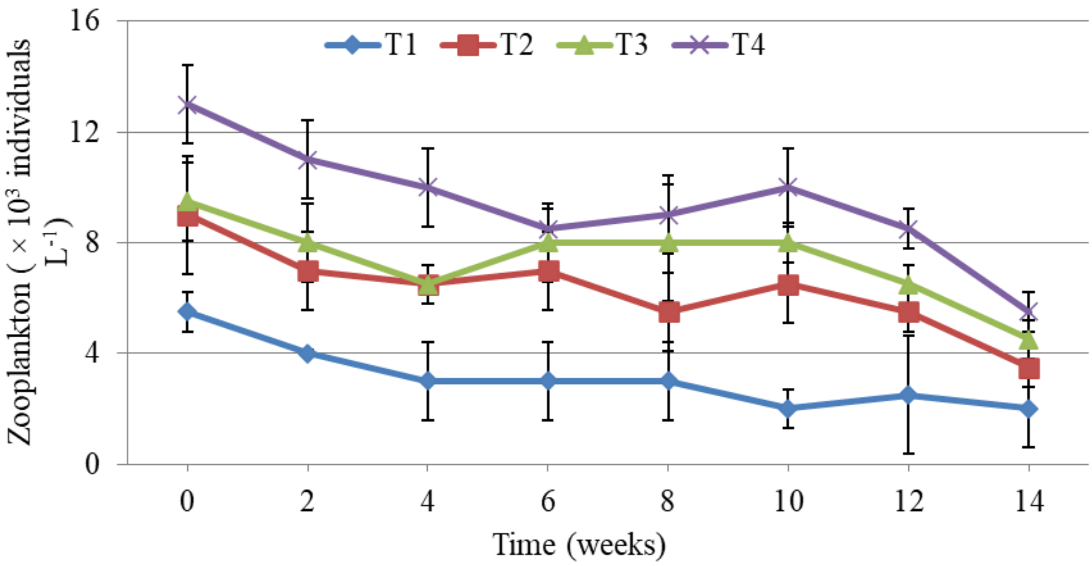

Figure 2. The fortnightly fluctuation of zooplankton among four treatments.

The maximum zooplankton genera and abundance were found in treatment T_4, where the highest amount of vermicompost was used and did not adversely affect the water quality parameters. There was an increasing trend of zooplankton population in the ponds treated with an expanding rate of vermicompost. The lowest zooplankton was found in T_1 where only feed was used. Most of the components of vermicompost are responsible for chlorophyll-a production, which is responsible for higher growth and development of phytoplankton (Bansal et al 2014). It is responsible for a higher abundance of zooplankton in vermicompost treated ponds. Phytoplankton population ranged from 8.40 $\times$ 10^3 to 15.02 $\times$ 10^3 individuals L^{-1}, 8.80 $\times$ 10^3 to 16.1 $\times$ 10^3 individuals L^{-1} and 1.6 $\times 10^3$ to 11.02 $\times$ 10^3 individuals L^{-1} with two groups of zooplankton recorded by Akter (2012), Alam (2012) and Bansal et al (2014) respectively. The groups and abundance of zooplankton of the present study showed consistency with the findings of the above mentioned researchers.

Growth performance of fish. Growth performance of monosex male tilapia in terms of weight gain under the same stocking density for 15 weeks from 20 May to 02 September is presented in Figure 3.

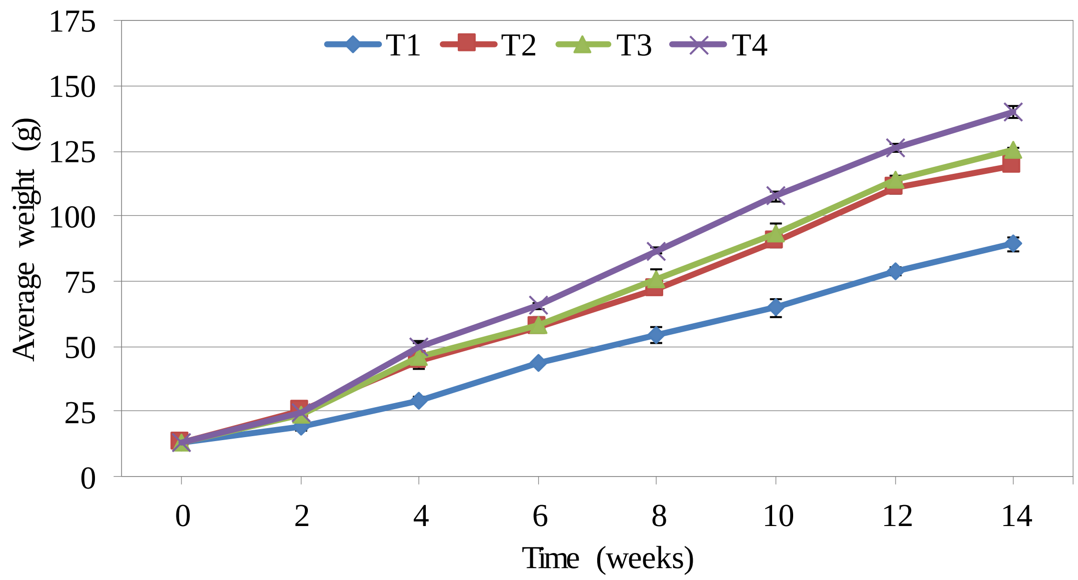

Figure 3. Average weight (g) of monosex *Oreochromis niloticus* in different treatments during the experimental period.

For the evaluation of proper growth performance of monosex male tilapia fry in different treatments during the experimental period, initial weight, final weight, % weight gain, SGR (% day^{-1}), survival rate (%) and total fish production (kg ha^{-1} 15 $weeks^{-1}$) were calculated and shown in Table 7.

Table 7

Stocking and harvesting size, survival rate, SGR and gross production of *Oreochromis niloticus* in different treatments during 15 weeks culture period

Item	*Treatments*				*LSD*	*Level of significance*
	T_1	T_2	T_3	T_4		
Initial mean weight (g $fish^{-1}$)	12.92±4.39^a	12.92±4.39^a	12.92±4.39^a	12.92±4.39^a	0.00	NS
Final mean weight (g $fish^{-1}$)	88.40±2.55^d	119.75±2.42^c	125.5±1.06^b	139.95±2.47^a	3.30	*
Mean weight gain (g $fish^{-1}$)	76.5±2.89^d	106.8±2.05^c	112.6±1.06^b	127.0±2.47^a	3.30	*
% Weight gain	591.95±19.7^d	826.86±15.87^c	871.75±8.21^b	983.20±19.15^a	25.56	*
Survival rate (%)	91.0± 0.07^a	91.0± 0’07^a	93.0±0.07^a	93.0±0.07^a	3.94	NS
SGR (% wt. gain day^{-1})	1.84±0.02^d	2.12±0.01^c	2.17±0.0^b	2.27±0.01^a	0.04	*
Gross production (ton ha^{-1} 15 $week^{-1}$)	3.50±0.07^c	4.79±0.12^b	4.91±0.06^b	5.60±0.14^a	0.29	*

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% significance level.

Final weight (g). The initial body weight of fry was 12.92 g during the stocking. There was no significant (P>0.01) difference in the initial weight of fish in different treatments (Table 7). The final weight of fish was 89.40±2.55 g in T_1, 119.75±2.05 g in $T_{2,}$

125.5±1.06 g in T_3 and 139.95±2.47 g in T_4. The maximum final weight was observed in treatment T_4 and minimum final weight was observed in treatment T_1 where only supplementary feed was applied (Table 7, Figure 4).

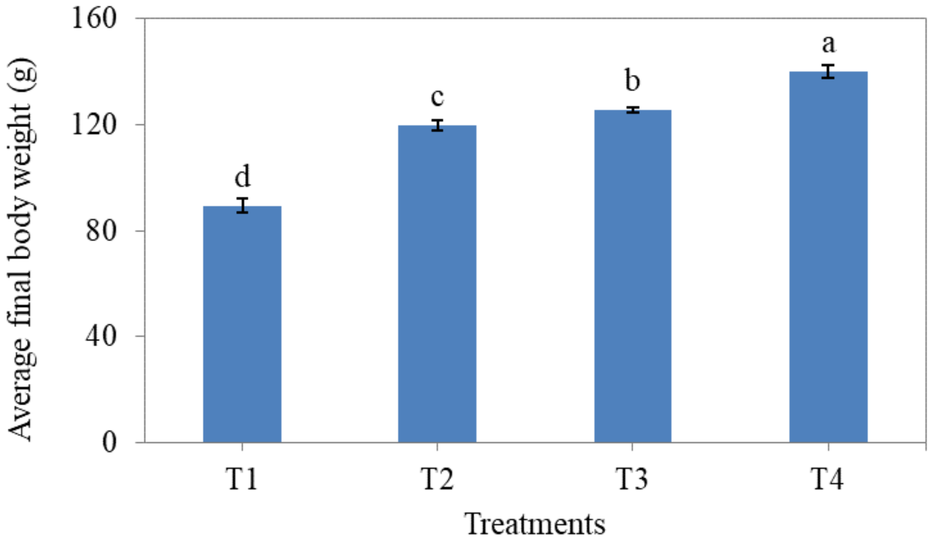

Figure 4. Average final body weight of *Oreochromis niloticus* among four treatments after 15 weeks of rearing.

Weight gain (g). The weight gain of fish was 76.5±2.55, 106.8±2.05, 112.6±1.06 and 127.0±2.47 g in T_1, T_2, T_3, and T_4 treatments, respectively (Figure 5). The highly significant ($P<0.01$) weight gain (127.0 g) was found in treatment T_4, where manuring with vermicompost was applied at the dose of 24,000 kg ha^{-1} $year^{-1}$ with 2% feed of body weight, and the lowest weight gain (76.5 g) was found in treatment T_1 where only supplementary feed was applied (Figure 5 and Table 7).

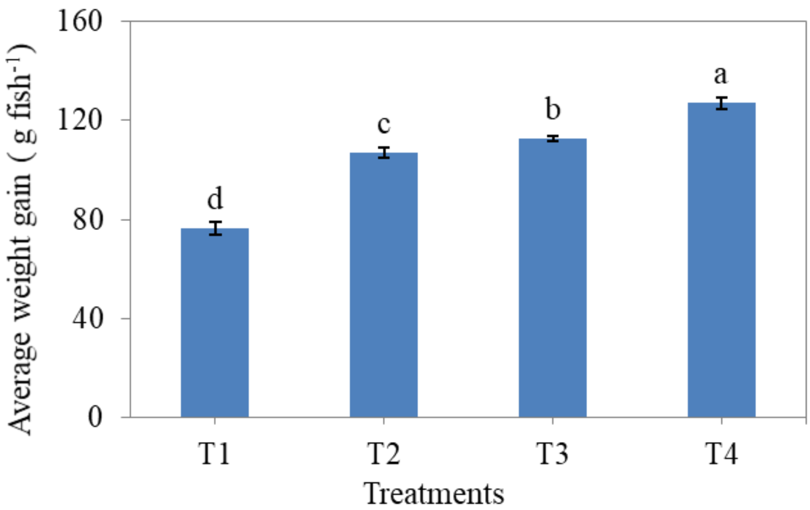

Figure 5. Average weight gain of *Oreochromis niloticus* among four treatments after 15 weeks of rearing.

Percent weight gain (%). The weight gain percent of fish was 591.95±19.70, 826.86±15.87, 871.75±8.21 and 983.20±19.15 for treatments T_1, T_2, T_3, and T_4, respectively. The highly significant ($P>0.01$) percent weight gain (983.20%) was observed in T_4 where manuring with vermicompost at the dose of 24,000 kg ha^{-1} $year^{-1}$ with 2% feed of body weight was applied. The minimum weight gain (591.95%) was observed in treatment T_1, where only supplementary feed was applyied (Table 7).

Specific growth rate (SGR % per day). The average values of the specific growth rate of monosex tilapia were 1.84±0.02, 2.12±0.01, 2.17±0.0 and 2.27±0.01 in treatments T_1, T_2, $T_{3,}$ and T_4 respectively. There were significant (P>0.01) differences in SGR among the different treatments (Table 7).

Survival rate (%). The survivability of monosex tilapia was 91.0±0.07, 91.0±0.07, 93.0±0.07 and 93.0±0.07% in treatments T_1, T_2, T_3 and T_4 respectively. There were no significant differences (p>0.05) in the survivability of fish among different treatments.

Production (ton ha^{-1} 15 weeks^{-1}). The gross production was 3.50±0.07, 4.79±0.12, 4.91±0.06 and 5.60±0.14 ton ha^{-1} 15 weeks^{-1} in treatments T_1, T_2, T_3 and T_4 respectively. The highly significant (P>0.01) gross fish production was 5.60±0.14 ton ha^{-1} 15 week^{-1} in T_4 under manuring of vermicompost at the dose of 24,000 kg ha^{-1} year$^{-1,}$ and the gross production was found to be increased significantly with the increase of vermicompost doses. The lowest gross production of 3.50±0.07 ton ha^{-1} 15 week^{-1} was observed in T_1 where only supplementary feed was used (Figure 6 and Table 7).

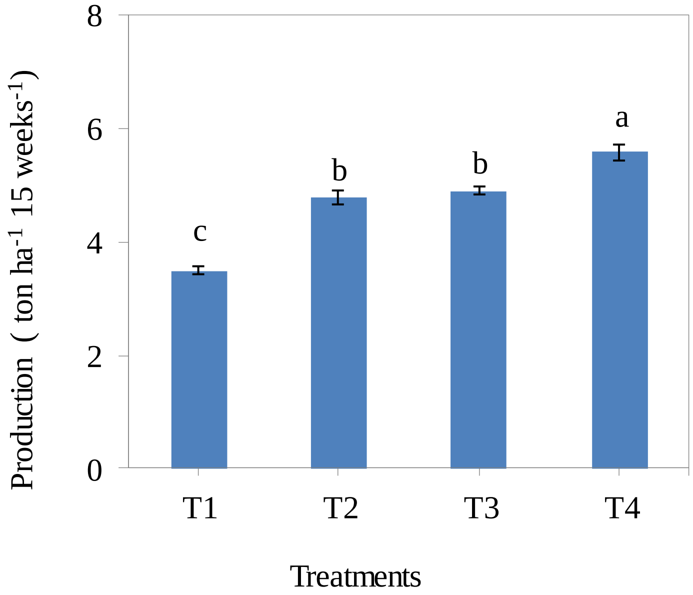

Figure 6. Gross production of *Oreochromis niloticus* among four treatments after 15 weeks of rearing.

The productivity was considerably higher in manured ponds than in the control ponds and the growth of fish was higher. Therefore it is recommended to manuring the fish cultured ponds especially of tilapia with vermicompost without affecting the waterquality parameters. The above results reveals that vermicompost of different doses did not adversely affect the physicochemical parameters of water. The density of phytoplankton and zooplankton were also significantly higher in treatments T_4 than T_3, T_2 than in control ponds T_1. The growth of tilapia was higher in treatment T_4 where fish were fed with 2% body weight of feed with vermicompost at a dose of 24,000 kg ha^{-1} year^{-1} than vermicompost at the dose of 16,000 kg ha^{-1} year^{-1}, vermicompost at dose of 8,000 kg ha^{-1} year^{-1} and control treatments where used only feed of 2% of body weight. This indicates that tilapia production can be increased in ponds treated with vermicompost at a dose of 24,000 kg ha^{-1} year^{-1}.

In the present study, the density of phytoplankton and zooplankton were significantly higher in treatments T_4 than T_3, T_2 and control ponds T_1. This may be due to a higher level of N, P and K in vermicompost which are released from vermicompost and ready in uptake form. Chakrabarty et al (2008, 2010) also recorded significantly higher plankton production that ultimately enhances the fish growth in vermicompost treated ponds as compared to traditionally used organic and inorganic fertilizers.

Economic analysis. The purpose of this topic is to determine the per hectare cost and return of vermicompost-based tilapia fish production in treatments T_2, T_3 and T_4, and T_1 (control) where only supplementary feed was used. Cost and returns were determined based on production. Full costs included the cost of all inputs except pond lease value. On the return side, net returns were calculated at the basis of total price getting by assuming the current market price of selling the total amount of tilapia fish harvested from the ponds of treatments T_1, T_2, T_3, and T_4 respectively. In the study, gross return was 916, 1285, 1301 and 1889 USD ha^{-1} 15 $week^{-1}$ in treatments T_1, T_2, T_3 and T_4, respectively (Table 8).

Table 8

Cost-benefit comparison of *Oreochromis niloticus* production under four treatments

Item	*Treatments*					*Level of significance*
	T1	T2	T3	T4	*LSD*	
Gross production (ton ha^{-1} 15 $week^{-1}$)	3.50 ± 0.07^c	4.79 ± 0.12^b	4.91 ± 0.06^b	5.60 ± 0.14^a	0.29	*
Total input cost (USD ha^{-1} 15 $week^{-1}$)	4033.0^c	5491.0^b	5649^b	6031^a	709	*
Total income (USD ha^{-1} 15 $week^{-1}$)	4949.0^b	6776.0^{ab}	6950^{ab}	7920.0^a	417	*
Net income (USD ha^{-1} 15 $week^{-1}$)	916.0^c	1285.0^b	1301.0^b	1889.0^a	802	*
BCR	1.22^b	1.24^{ab}	1.23^{ab}	1.30^a	0.17	*

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

Net income. The net income was 916, 1,285, 1301 and 1889 USD ha^{-1} 15 $weeks^{-1}$ in T_1, T_2, T_3 and T_4 treatments, respectively (Figure 7). In the case of T_4, the gross income and net income were the highest, although the total cost found to be the highest with higher gain production in T_4. In contrast, the net profit was the lowest in treatment T_1 (Figure 7 and Table 8).

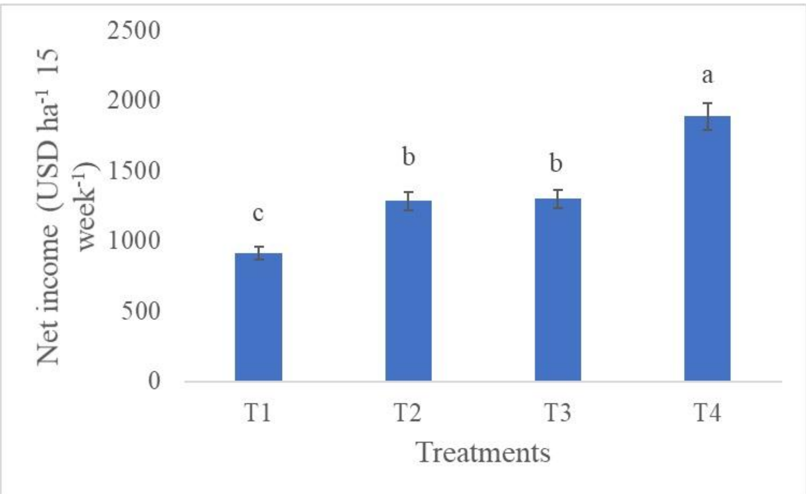

Figure 7. Net income in different treatments during the study period after 15 weeks of rearing.

Ahmed et al (2013) obtained a net income (USD ha^{-1} 70 $days^{-1}$) of 1,012 in tilapia culture. However, in the present study, the highest net income from tilapia culture was 1,889 USD where vermicompost at the dose of 24,000 kg ha^{-1} $year^{-1}$ and feeding artificial feed with 2% body weight of fish was applied. The market price of tilapia is considered as 1.42 USD kg^{-1} fish. Thus, the present study implies that the net income of tilapia culture can be increased using vermicompost with minimizing feeding ration in T_4 and can be ensured both financial and nutritional support to the fish farmers.

Conclusions. Based on the results of the experiment, it can be concluded that all sorts of water quality parameters were desirable in T_4 under manuring with vermicompost at the dose of 24,000 kg ha^{-1} $year^{-1}$. Also the production of monosex tilapia was maximum in treatment T_4. According to the findings of the present study, it may be concluded that the application of vermicompost at a dose of 24,000 kg ha^{-1} $year^{-1}$ with supplementary feed of 2% body weight of fish will be cost-effective for tilapia culture in pond. Fish farmers can easily adopt this technology because vermicompost can be easily produced from cow dung using red worms. Hence this technology might play a vital role in pond fish culture to increase fish production with minimum cost. For minimizing the production cost of fish culture to a greater extent, vermicompost-based tilapia culture method can be adopted by farmers easily. Therefore, this system of culture technology can be an economically viable and sustainable technology that may be recommended to the fish farmers of the country for improving their livelihoods on the basis of the economic aspect.

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