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Effect of organic and inorganic fertilizers on survival and performance of African catfish fry produced under artificial propagation

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Abstract
This study was conducted to determine the effect of organic and inorganic fertilizers on the survival and performance of African catfish fry produced under artificial propagation in a fish pond for sixty days. Two types of fertilizers chicken manure, di-ammonium phosphate (DAP), and a Control group with no fertilizer were tested in triplicate using nine concrete ponds of 10 m^2. Zooplankton abundance, growth performance, and survival rate of *Clarias gariepinus* fry were determined. One-way analysis of variance (ANOVA) was used to determine differences between treatments (p>0.05). Duncan's Multiple Range Test (DMRT) was done where significant differences existed between treatments. Results indicated that zooplankton abundance, fry growth response, and performance index (PI) were significantly higher (p<0.05) in chicken manure-applied ponds compared to DAP fertilizer and no fertilizer-applied ponds. There was a significant difference (p<0.05) in fry survival between no fertilizer-applied ponds, chicken manure, and DAP-fertilized ponds. Water quality parameters were within the optimum range.

Keywords: Chicken manure, Clarias gariepinus, DAP, Survival, growth performance, zooplankton

1. Introduction

Fertilization of aquaculture ponds increases the productivity of phytoplankton which is the food base of zooplankton and benthic animals (Mischke, 2012) [26]. Pond fertilization with livestock wastes is widely used in many countries in sustaining the productivity of the pond at the minimum expense (Peker and Olah, 1990) [34]. The main purpose of pond fertilization is to augment plankton production to serve as naturally available food for the fish; since both autotrophic and heterotrophic organisms are stimulated by pond fertilization which increases fish production (Grag and Bhatnagar, 2000) [19].

Recently, Catfish species culture belonging to the Clariid family is gaining fast global attention (Adewolu *et al*., 2008) [1]. The fast growth rate, hardiness, air-breathing nature, better selling price, and easiness of artificial propagation of *C. gariepinus* made it best for aquaculture (Olurin *et al*., 2012, Ndimele and Owodeinde, 2012) [32, 30].

The rearing of fish embryos (fry and post-fry) is the most critical aspect of aquaculture (Mylonas *et al*., 2010; Bardon and Eric, 2017) [29, 9]. Fish at these stages are very delicate and highly sensitive to the various factors of production. Stocking density (Schrma *et al*., 2006) [35] and water quality parameters (Brazil and Wolters, 2002) [12] are some of the factors. High aggressiveness of African catfish juveniles is expected in normal conditions when they are confined in small numbers in a large volume of water (Hengsawat *et al*., 1997; Toko *et al*., 2007) [42, 42]. However, aggressiveness can result in stock losses, reduced food conversion efficiency, and slower growth (Mosha *et al*., 2017) [28]. In intensive catfish culture, the water quality mainly dissolved oxygen, and pH levels are considered as limiting factors (Brazil and Wolters, 2002; Pangni *et al*., 2008) [12, 33].

Olurin *et al* (2012) [32] proved that *C. gariepinus* larvae rearing to juveniles were challenging due to their small size and absence of a functional digestive system. Significant losses are incurred in the hatchery, as fry weans over from yolk absorption to exogenous feeding (Adewumi, 2015) [2].

The Bahir Dar Fisheries and Other Aquatic Life Research Center (BFALRC) also experienced such a terrible loss of larvae ranging from 90% to 100% after yolk absorption (Unpublished data). Larvae's inability to accept large feeds and assimilate protein from dry-formulated diets contributes to such a loss (Cahu and Zambonino, 2001) [14]. Although Artemia nauplii and decapsulated cysts were used for the first feeding of most fish larvae with successful outcomes (Olurin *et al*., 2012; Agadjihouede *et al*., 2012) [32, 3]. However, its expensive price makes it not readily available to most of the developing countries' poor subsistence fishermen, usually in sub-Saharan Africa (Agdjihouede *et al*., 2012). Based on the above factors. Due to this fact, providing larvae with live zooplankton or algae is important before sequential acclimatization to start dry-formulated diets (Olurin and Oluwo, 2010) [31]. Despite significant progress made in aquaculture, *C. gariepinus* production was tampered with by larvae rearing. So, improvement of *C. gariepinus* growth performance and survival can be made possible by using naturally available live food at an earlier development stage of fry.

Therefore, the objective of the present study was to determine the effect of organic and inorganic fertilizers on the survival and growth performance of African catfish.

Materials and Methods

This study was carried out between August 2020 and October 2020 using concrete ponds facilities of the Bahir Dar Fisheries and Other Aquatic Life Research Centre. Fish fingerlings of *C. gariepinus* were procured from BFALRC, reared artificially using catfish pituitary, and acclimatized in 180-liter capacity glass aquaria for five days. The study was conducted in nine concrete ponds of 15 m^3 capacity. The experimental concrete ponds were cleaned; forest soil was spread to 10 cm high and left for fifteen days. After fifteen days, ponds were filled with water at 80 cm depth. The water in the ponds was allowed to stabilize for 5 days before fertilization. The 60 days experiment consisted of the following treatments along with Control. Nine concrete ponds having an area of $10m^2$ each were taken for three treatments each with triplicates. The experimental ponds were designated as T_1: T_1M_1—T_1M_3 and were randomly assigned to the ponds. The ration treatment included the daily application of grounded tilapia pelleted fish feeds at 5% body weight. Pelleted fish feed was purchased from a local agro-input shop in Bahir Dar city from the sub-dealer of Livestock Feed manufacturer Alema Koudij Feed with 35% crude protein, 4% fiber, 7% fat, 2% calcium, and 52% carbohydrate contents as indicated on the flyer inside the package and chicken manure (collected from a local private poultry farm) at the rate of 2,000 kg/ha/month. A 5% body weight daily ratio was taken after Ashley-dejo *et al*. (2014) [6] since 5% body weight has been found to be sufficient for maximum growth for a number of fish species at the fingerlings and juveniles' stages of life. T_2 designated as T_2F_1—T_2F_3 with the same feed and 20 g of di-ammonium phosphate (DAP) fertilizer (Source Weramit Horticulture Research Sub Center) and Control: C1—C3 no fertilizer offered with same supplementary feed only. The inorganic fertilizer DAP application was based on Boyd (2003) [13] recommendation on chemical fertilizers in pond aquaculture.

To use *Daphnia magna* zooplankton as natural food for the larvae, 50 individuals of *D. magna* were stocked in all nine concrete ponds, from the BFALRC limnology facility one week before fry stockings. After fifteen days of fertilization, all the ponds were stocked at the rate of 20 fry/m^2 with 5-day-old *C. gariepinus* fry. The average weight of the fry was 0.013±0.0 g and the average length was 8.56±0.14 mm. All nine concrete ponds were covered with nylon mosquito nets to prevent predators. Fertilization was repeated every two weeks for two months. For the first month, the sample of catfish fry from each concrete pond was harvested using a seine net, and placed in a 10-l bucket. In the laboratory, they were weighed using an electrical digital balance with a capacity of 300 g and 0.01 g precision, and live length was measured with a mini ichtyometer to the nearest 1 mm. Fries were anesthetized in 0.001% Trican methane sulfonate (MS 222, Crescent Research Chemical, Phoenix, Arizona 85,044, USA) before measuring live body length and body weight. The water quality parameters (temperature, dissolved oxygen [DO], pH, salinity, total dissolved solids (TDS), and conductivity) of the experimental ponds were also recorded during sampling using YSI multimeter model 556 MPS. The following formula was used to determine fry performance and survival rate as outlined by the Kang'ombe *et al* (2006) [24].

1. **Mean live weight gain = FMW-IMW**

Where FMW = final mean weight (g/fish), IMW = initial mean weight (g/fish)

Mean lives length gain (mm) = FML—IML

Where FML = final mean length (mm/fish), IML = initial mean length (mm/fish)

2. Relative growth rate (RGR) % = $\frac{\text{Wf}-\text{Wi}}{\text{Wi X t}} X\ 100$

Where Wi = initial weight of fish (g), Wf = final weight of fish (g), t = duration of the experiment in days.

3. Specific Growth Rate (SGR) % = $\frac{\text{lnWf}-\text{lnWi}}{t} X\ 100$

Where ln = the natural logarithm, t = duration of the experiment in days.

4. Average Daily Growth (ADG)% = $\frac{\text{Wf}-\text{Wi}}{t} X\ 100$

5. Performance index (PI) was calculated

6. PI = Survival rate x $\frac{\text{Wf}-\text{Wi}}{t}$ (Mohanty, 2004). [27]

Where Wf is mean final weight, Wi is mean initial weight and t is rearing period.

7. **Quantitative study of zooplankton**

Ten-liter water samples were collected from 4 different locations and depths (1m) within each concrete pond for all nine ponds and passed through a 25 µ mesh plankton net (Wetzel and Likens, 1991) [43]. The collected plankton samples were preserved in 5% buffered formalin in small plastic tubes. The preserved plankton samples were counted using a Sedgewick-Rafter counting cell, under a stereo binocular microscope (Motic). A 1 ml subsample from each of the samples was transferred to the cell, after which all zooplankton, present on 10 squares of cells chosen randomly, were counted and later were used for quantitative estimation using the following method and formula given by Stirling (1985) [39].

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

Where

N = Number of plankton cells or units per liter of original water.

A: Total no of zooplankton counted

C: Volume of final concentration of the samples in ml

V: Volume of a field in mm^3

F: Number of fields counted

N: Volume of original water in liters

For statistical analysis, a comparison of treatment means using one-way analysis of variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) (Duncan, 1955) [15] was performed to compare the different treatment means at a 5% level of significance. Data were analyzed using Statgraphics Centurion 19 statistical software.

Results

Treatments with chicken manure, inorganic fertilizer (DAP), and treatments with no fertilizer caused greater changes in water quality parameters. The physicochemical parameters temperature, dissolved oxygen, pH, salinity, and TDS were found in the optimum range in all treated ponds, but no statistically significant difference was observed with the fertilizer types (Table 1). While T_1 shows a statistically significant difference (p<0.05) in the concentration of salinity, TDS and conductivity compared to other treatments T_2 and Control. However, there is no statistical difference between treatment T_2 and Control (p <0.05).

The results of *Daphnia magna* population density in the pond treated with chicken manure (T_1) exhibited the highest record in the numbers of *Daphnia magna* (1875.73±3.28 no/l) followed by no fertilizer applied pond (190.93±2.28 no/l). The mean value of the number of *Daphnia magna* in T_2 was the lowest (147.47±0.49 no/l). There was a significant difference in *Daphnia magna* density among treatment T_1, T_2, and Control.

Table 1: Physico-chemical parameters of the ponds with different treatment (Mean ±SE)

Parameter	Chicken manure	DAP fertilizer	Control	P-Values
Temp (^{0}C)	24.42±0.43^a	24.49±0.47^a	24.84±0.53^a	0.802
DO (mg/L)	5.78±0.25^a	6.21±0.32^a	5.73±0.21^a	0.372
Salinity (ppm)	0.09±0.00^a	0.06±0.00^b	0.06±0.00^b	0.00
TDS (mg/L)	0.12±0.00^a	0.08±0.00^b	0.09±0.00^b	0.00
Conductivity (µs/cm)	0.18±0.00^a	0.12±0.01^b	0.14±0.01^b	0.00
pH	7.92±0.39^a	8.18±0.29^a	8.05±0.38^a	0.882

Means with different letters in the same rows are significantly different (Tukey's multiple range test at p <0.05). (DO: dissolved oxygen; TDS: total dissolved solids)

The growth response of *C. gariepinus* (Table 2) showed that T_1 had the highest mean final weight during the 30 and 60 days of the experiment, followed by Control while the least mean value was recorded in T_2. The value of the mean final weight of fish among the three treatments (T_1—Control) was significantly different (p<0.05). The mean weight gain follows the same trend as the mean final weight in this study (Table 2).

Table 2: Growth response of *C. gariepinus* stocked in concrete pond fertilized with different fertilizers (chicken manure, di-ammonium fertilizer, and no fertilizer) for 30 and 60 days (Mean±SE).

Parameters	Chicken manure		DAP fertilizer		Control	
	30 days	60 days	30 days	60 days	30 days	60 days
IMW (g)	0.01±0.0	0.01±0.0	0.01±0.0	0.013±0.0	0.01±0.0	0.013±0.0
FMW (g)	6.99±0.36^a	10.77±0.35^a	0.24±0.01^b	1.42±0.09^b	0.42±0.02^c	2.82±0.12^c
WG (g)	6.98±0.36^a	10.76±0.35^a	0.23±0.01^b	1.41±0.09^b	0.41±0.02^c	1.59±0.09^c
SGR (%)	9.08±0.06^a	9.52±0.03^a	5.74±0.05^b	7.48±0.04^b	6.28±0.04^c	8.06±0.05^c
RGR (%)	895.69±46.05^a	1379.07±44.26^a	29.42±1.66^b	180.47±11.55^b	51.51±2.47^c	361.52±15.09^c
ADG (%)	11.64±0.59^a	17.93±0.58^a	0.38±0.02^b	2.35±0.15^b	0.67±0.03^c	4.69±0.19^c
S%	NA	31.33	NA	21.17	NA	35.17
PI	NA	9.36±0.30^a	NA	0.83±0.05^b	NA	2.75±0.12^c

Means with different superscripts indicate significant differences (Tukey's multiple range test at p<0.05). (ADG: average daily growth; DAP: di-ammonium phosphate; FMW: final mean weight; IMW: initial mean weight; NA: none pplicable P: Performance Index; RGR: relative growth rate; S: survival; SGR: specific growth rate; WG: Weight gain)

The highest specific growth rate (SGR) was recorded in the pond fertilized with chicken manure (T_1) while the least value of SGR was recorded in ponds fertilized with DAP (T_2) (Table 2). Consequently, there was a significant difference (p<0.05) in the specific growth rate among the treatments. The daily growth rate (DGR) of fish in all the treatments followed a similar trend as the specific growth rate with statistically significant differences among the three treatments (T_1-Control) (Table 2).

In this study, the average survival rate of *C. gariepinus* was not found satisfactory, and comparatively lower fish records were found in T_2 (Table 2). The highest (35.17%) survival rate of *C. gariepinus* was in Control and the lowest (21.17%) was in T_2. However, the percentage of survival among the three treatments (T_1-Control) was statistically different (p<0.05) (Table 2).

The highest performance index was recorded in T_1 (pond fertilized with chicken manure) and it was significantly different (p<0.05) as compared to other treatments T_2 (pond fertilized with DAP) and control (pond with no fertilizer) and pond with no fertilizer applied (Table 2). The least value performance index was recorded in treatment ponds fertilized with DAP fertilizer (T_2) (Table 2).

The present study revealed a steady increase in the weight of *C. gariepinus* in experimental ponds treated with chicken manure as compared to DAP fertilized ponds with no fertilizer applied. Significantly, higher growth of fish was recorded in T_1. However, the extreme maximum individual live weight of the catfish fry record was 27.44 g with

22.9 cm total length in ponds fertilized with chicken manure (T_1) followed by catfish fry from pond with no fertilizer (T_3) having 6.82 g weight with 10.70 cm total length, and catfish fry from ponds fertilized with DAP fertilizer (T_2) exhibit 3.87 g weight and 7.8 cm total length whereas 11.19% specific weight gain was obtained from pond fertilized with chicken manure (T_1).

During the 30 and 60 culture days, the body length and body weight measurement of catfish fry under different treatments in chicken manure fertilized ponds (T_1) showed highly significant variation (Fig.1-2). Ponds fertilized with DAP fertilizer (T_2) were the lowest. During the 60 culture days catfish fries from chicken manure fertilized ponds showed a 7.63 and 6.77-fold weight gain and 9- and 6-fold growth increment over the catfish fry from DAP fertilized and no fertilized applied ponds respectively (Fig. 2). Whereas during the 60-culture day catfish fries from chicken manure fertilized ponds showed a 2.33- and 1.89-fold length gain and 2.25- and 2-fold growth increment in length were recorded for catfish fry from DAP fertilized and no fertilized applied ponds respectively (Fig. 1).

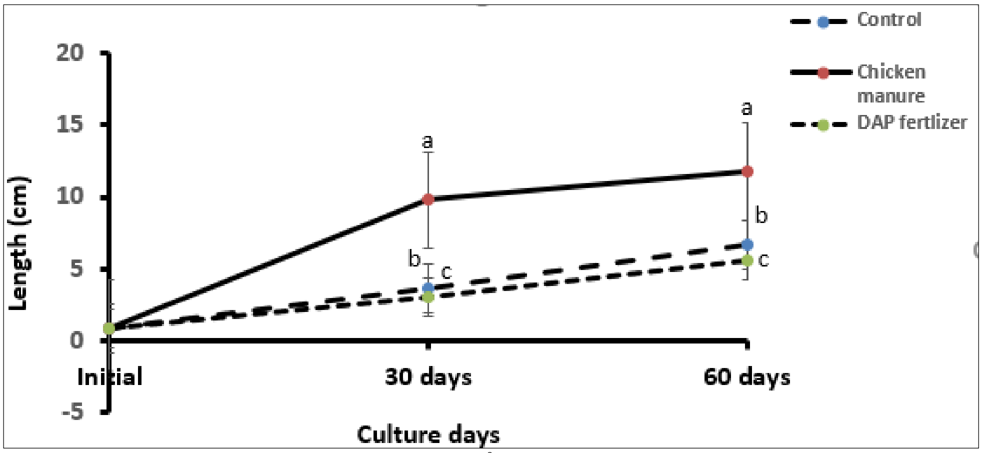

Fig 1: Measurements of body length (cm) of *C. gariepinus* under different treatments for 30 and 60 days (Mean±SE). [Bars with different letters are significantly different [Duncan's Multiple Range Test at p <0.05]. (DAP: di-ammonium phosphate)

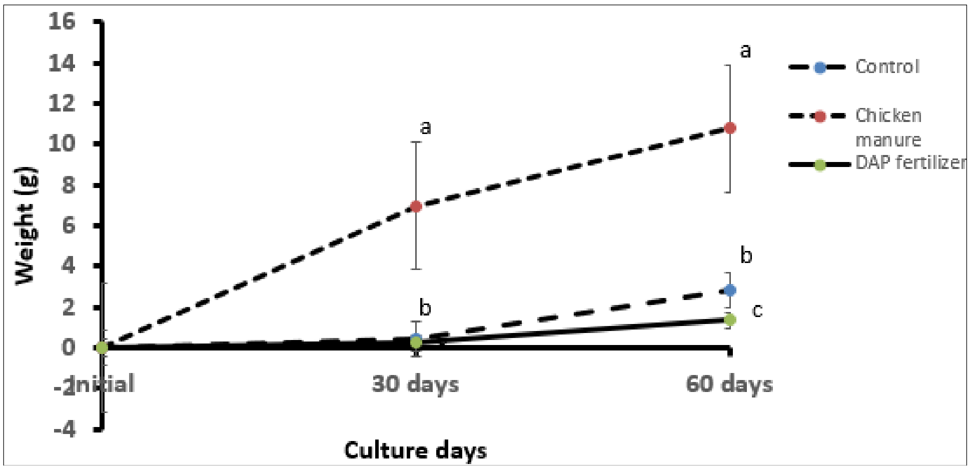

Fig 2: Measurements of body weight (g) of *C. gariepinus* under different treatments for 30 and 60 days (Mean ±SE). [Bars with different letters are significantly different [Duncan's Multiple Range Test at *p*<0.05] (DAP: di-ammonium phosphate)

Discussion

The dissolved oxygen concentrations in ponds fertilized with chicken manure (T_1) were the lowest (5.78±0.25) compared to ponds fertilized with DAP (6.21±0.32) (Table 1). This might be attributed to the aerobic bacterial decomposition activities on manure that demanded high oxygen for respiration. Because heterotrophic bacteria consume oxygen and release carbon dioxide during the oxidizing process of the organic matter of chicken manure. On the other hand, the higher abundance of zooplankton might also bring a concentration decline as compared to ponds fertilized with DAP (T_2) to no fertilizer applied ponds (T_3) (Table 1). The significantly higher variation in DO concentration in ponds fertilized with DAP (T_2) (6.21±0.32) compared to ponds fertilized with chicken manure (T_2) (5.78±0.25) and ponds with no fertilizer applied (T_3) (5.73±0.21) (Table 1) strengthen the above assertion due to low abundance of zooplankton in ponds fertilized with DAP (T_2). This result is consistent with those reported by Bhakta *et al*. (2006) [10] and Kaur *et al*. (2015) [25]. The amount of higher fertilization level causes a raise of all the water quality parameters at the desirable range with the exception of dissolved oxygen level showed a variation at dawn when a high manuring rate was applied (Shevgoor *et al*., 1994) [36]. However, the values of DO in the present study were in the desirable limit as warm-water fish requires DO ≥ 5 mg/l for growth and reproduction (Swingle, 1969) [41] (Table 1).

Zooplankton abundance was higher in ponds fertilized with chicken manure (T_1) than in ponds fertilized by DAP fertilizer (T_1) and with no fertilizer applied ponds (T3) control group. This might be due to the organic fertilizers require bacteria and other microbes for decomposition, and thus offer a wider plankton diversity in fish ponds, particularly zooplankton (Soderberg, 2012) [37]. Also, chicken manure has been reported to provide a substrate for zooplankton production (FAO, 2003) [17] which enhances high diversity and abundance. Fang *et al*. (1986) [16] carries out an experiment with chicken and pig manure in ponds and they reported that chicken manure was suitable for plankton production. Bhanot *et al*. (1991) [11] reported that organic fertilizers, especially poultry manure-treated ponds, gave a comparatively higher production of zooplankton. Also, Hossain *et al*. (2006) [21] reported more or less similar findings to the present study. The lowest zooplankton abundance was recorded in ponds fertilized by DAP (T2) might be due to the application of DAP granules which were coming in direct contact with the pond mud as phosphorus in the fertilizer becomes trapped in the mud and unavailable to the algae (Jesse, 2008) [23].

The growth performance of catfish fry was higher in chicken manure fertilized ponds (T_1) compared to DAP fertilized ponds (T_2) and ponds without fertilizer applied (Table 2). This might be attributed to the presence of catfish fries natural feed organisms (zooplankton) were highly abundant in the chicken manure fertilized ponds this situation supported bulk production of phytoplankton which is a readily available feed for the zooplankton (Bahnasawy, 2009) [7]. Similar results have been reported by Mosha *et al*. (2017) [28].

A higher survival rate of catfish fries was observed in unfertilized ponds (T_3) and ponds fertilized with chicken manure (T_1) (Table 2). On the contrary, Sophin and Preston (2001) [38] reported that tilapia showed lower survival rates in chicken manure-fertilized ponds as compared to the inorganic fertilizer (urea and DAP) and unfertilized ponds. Similarly, Mosha *et al*. (2017) [28] reported that a higher survival rate of *C. gariepinus* fries was observed in tanks fertilized with DAP fertilizer and unfertilized ponds than in chicken manure-fertilized tanks under low stocking density.

Gamal *et al*. (2008) [18] in their study reported that low stocking density (5 fingerlings/m^2) in tanks fertilized by inorganic fertilizer (Urea + monophosphate) and chicken manure have the highest survival rate (96.48%) of catfish which indicated that cannibalism behavior of catfish increases with stocking densities. This might be due to the low dissolved oxygen and NO_2 concentration record.

Jamabo and Keremah (2009) [22] also reported that survival rate, mean body weight, mean total length and specific growth rate are stocking density-dependent for *C. gariepinus* fingerlings, which substantiates the findings of the present study. The low survival rate of catfish fries in ponds without fertilization (T_3) might be the cannibalistic behavior of the fish. Appelbaum and Damme (2007) [5] reported that cannibalism is the main cause of mortality and is responsible for losses of up to 28% after 45 days.

Cannibalism is influenced by stocking density, food availability, and size (Al-Hafedh and Ali, 2004) [4]. Suziki *et al*. (2001) [44] observed that increase in stocking density will lead to higher energy dissipation causing a reduction in growth rate and food utilization. According to Mosha *et al.* (2017) [28] growth performance of catfish, fry was higher under low stocking density (5 fry/m^2) compared to high stocking density (10 fry/m^2) with fertilizer types (chicken manure and DAP) and no fertilizer applied experiment. On the contrary in this study, the fish stocked at a higher density of 20 fish/m^2 which resulted in low survival rate (Table 2). In addition, Baskerville-Bridges and Kling (2000) [8] reported a greater risk of mortality at high stocking densities as a result of deteriorating water quality.

Conclusion

This study showed that zooplankton abundance, catfish fry growth response and performance index (PI) were highly significant in ponds fertilized with chicken manure. From these perspectives, we conclude that for better growth and survival in aquaculture practices, catfish fry may be raised successfully in chicken manure fertilized ponds.

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