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Impact of Diverse Fertilization Practices and Supplementary Feeding Regimes on Water Quality, Plankton Abundance, Growth, Survival, Blood Parameters, and Economic Returns of Grey Mullet (*Mugil cephalus*) in Nursery Ponds

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Abstract

The grey mullet (*Mugil cephalus*) is a significant aquaculture species known for its rapid growth, versatility, and high market demand. However, nursery-stage mortality, slow development, and high production costs continue to limit its profitability, particularly in earthen pond systems. One of the most significant issues is a lack of standardized and cost-effective feeding and fertilization systems that may optimize natural food production, maintain appropriate water quality, and improve fry survival and growth. The current study examines how various fertilizers and feeding techniques affect the water quality, plankton quantity, growth performance, survival rate, certain blood parameters, and economic assessment of raising grey mullet (Mugil cephalus) fries in eastern ponds. For seven months, grey mullet fries weighing 0.35±0.02 g were planted in nine earthen ponds (1000 m2 each) at a pace of 50,000 seeds. Three treatments were studied in triplicate: organic fertilizer with aquafood (T1), inorganic fertilizer with aquafood (T2), and aquafood only (T3). The measured water parameters were determined to be within an optimal range during the study period, with significant ($P<0.05$) changes in pH and ammonia concentrations across treatments. When comparing T1 to the other treatments, phytoplankton and zooplankton numbers showed considerably ($P<0.05$) higher values. The findings also show that compared to other groups, T1 showed a highly significant ($P<0.05$) increase in final body weight, weight gain, daily gain weight rate, and specific growth rate. T1 had the highest survival rate (60%), followed by T2 (57%) and T3 (55%). Basic hematological measures such as hemoglobin concentration (Hb), red blood cell count (RBCs), and hematocrit (Ht) showed substantial ($P<0.05$) changes. Furthermore, T1 achieved the highest benefit-cost ratio of 1.42, while T2 and T3 achieved 1.32 and 1.26, respectively. This approach came to the conclusion that the optimal nursery pond management for improving grey mullet survival and growth as well as raising the financial returns was to use organic fertilizers with aquafeed as a feeding strategy.

Introduction

In recent decades, the aquaculture industry has experienced rapid growth in response to the high demand for farmed fish due to global population growth (Alqahtani et al*.,* 2025). This industry remains a central source of economic prosperity and livelihoods for millions of individuals worldwide (FAO, 2016; El-Sayed et al*.,* 2025). Moreover, there are economic pressures to reduce the production costs of farmed species (Nasr-Allah & Nassrallah, 2017). Improving management practices could be achieved by increasing production and reducing costs of farmed species through the employed feed and fertilization practices (Edwards, 2015; Ghanem et al*.,* 2025). Therfore, using organic and inorganic fertilizers is the usual practice to stimulate and improve natural fish food organisms particularly the plankton which serves as the base of the pond's natural food web and offers supplementary ecosystem services (Das et al., 2020; Green, 2022). Fish growth is closely linked to phytoplankton and zooplankton productivity resulting from fertilization, which are essential requirements for achieving high fish growth and productivity (Jasmine et al., 2011). However, excessive fertilization can lead to algae proliferation and deterioration in water quality, negatively affecting fish growth and increasing the likelihood of disease and mortality (Kumar et al., 2019). Therefore, it is imperative to establish standard feed and fertilization concentrations to maximize the benefits of feeds and fertilizers for cost reduction and farm profit enhancement (Shaker et al., 2016; Mahnaty et al., 2019). Numerous studies have demonstrated the utilization of inorganic and organic fertilizers in fish ponds for sustained primary productivity, growth, survival and economic returns in different fishes as Nile tilapia, catfish, carp and mullet (Biswas et al., 2017; Abdel-Wahed et al., 2018; Li et al., 2025).

Mullets are the second most farmed species after tilapia and constitute about 22% of the national aquaculture production (FAO, 2024). Being an economic species with a commercial value, *Mugil cephalus* is one of the most important mullet species broadly cultured in both brackish and freshwater as well as mono and polyculture fish ponds (Parrino et al., 2018; Kumar et al., 2021). Simplicity of cultivation, tolerance to a varied environmental conditions range, superior growth, good flesh quality as well as resistance to poor water quality and disease make *Mugil cephalus* suitable for aquaculture (Quirós-Pozo et al., 2023). Egypt is the largest producer of farmed mullets, with a production of approximately 351 thousand tonnes, constituting around 97% of the global production. Mullet's rearing depends entirely on the assortment of wild seeds, and the quantity collected in Egypt, for example, amounts to approximately 3.3 billion seeds, with a survival rate reaching nearly 54% during the nursery and grow-out stages (Abdel-Hady et al., 2024). According to Saleh (2008), the majority of grey mullet mortalities occur during the nursery stage. Inadequate pond preparation and management may lead to significant losses due to predation and oxygen depletion, particularly in heavily fertilized ponds. Losses may also occur during fingerling harvesting (Saleh, 1991).

Sipauba-Tavares et al. (2013) revealed that optimal fish growth and high production necessitate the provision of necessary balanced nutrients via fertilization. Fertilizers have been used to boost fish pond fertility, fish development, and productivity while posing no dietary risks (Terziyski et al., 2007; Kumar et al., 2019).

Despite its significance, the mullet seed nursery stage has not received much attention (Yasmin et al., 2016; Kumar et al., 2021). According to Biswas et al. (2017), the periphyton-based system provides a viable and ecologically beneficial method for producing grey mullet (Mugil cephalus) fingerlings in low-salinity, fertilized ponds. Additionally, El-Hawarry (2018) explained that the availability of food and the expansion of earthen ponds utilized for Mugil cephalus and Mugil capito polyculture during the nursery age had synergistic effects to produce high-quality fry with the desired indicated size. Therefore, the most crucial elements that lower nursery stage mortality rates and increase profitability are determining the best management approaches, such as feeding and fertilization techniques. With an emphasis on increasing survival, development, pond production, and financial returns, the goal of this study is to identify the best feed and fertilization techniques for strengthening the nursery performance of grey mullet (*Mugil cephalus*). In particular, the study aims to determine standardized and economical feeding and fertilization schedules that optimize natural food availability, promote healthy fry development, lower nursery stage mortality, and ultimately increase mullet aquaculture's sustainability and profitability.

Material and Methods

Experimental Design

The experiment was conducted at a private fish farm with clay ponds in the Sharkia governorate in Egypt. The seeds of grey mullet (Mugil cephalus), weighing an average of 0.35±0.02 grams at first, were collected from the wild and bought from a seed vendor. Furthermore, commercial aquafeeds that were processed into powder and included 25% protein from a reputable business (Skretting) were utilized.

The experiment commenced in early October 2021 and accomplished at the end of April 2022. Before the beginning of the experiment, the earthen ponds were prepared by sun-drying for two weeks. Agricultural lime ($CaCO_3$) was then applied to the bottom of each pond at a rate of 300 kg per hectare. Initial fertilization of the ponds was conducted at the beginning of the fourth week, with a mixture comprising 7000 kg of organic fertilizer (chicken manure), 70 kg urea (45% N), and 24 kg triple superphosphate (15% P_2O_5) per hectare. A battery-cage housing system was employed in all the farms. Nine samples of chicken manures were gathered from the poultry shed maintained under dip litter system at three different poultry farms. Three representative poultry manure samples were collected in plastic bottles (2 liter) from each farm, stored at 4°C and transported to the laboratory for subsequent chemical characterization (Table 1). After evaporating water at 105°C, the moisture was calculated by the loss of weight in the sample. Then, ash content and organic matter (OM) were assessed using UNE-EN13039 protocol. Afterward, carbon, hydrogen and nitrogen contents were measured by means of a Perkin–Elmer

2400 Elemental Analyzer and a Perkin–Elmer AD-2Z Microbalance according to Quiroga et al. (2010) procedure. A Shimadzu TOC 5000A was used to determine the total organic carbon (TOC) in the samples. While, the content in Phosphorous, Chlorine in addition to Sulphur was assessed by ion chromatography via an 861 Advanced Compact IC following the method of Colina & Gardiner (1999).

Subsequently, the water inlet and outlet pipes of the ponds were enclosed with narrow mesh screens to prevent unwanted fish or predators from entering. The water level in the ponds was gradually raised, with an average depth of 1.25 meters. At the end of the fourth week, the seeds were introduced into the ponds after acclimatization.

Each treatment, comprising three replicated ponds, was designed based on fertilization and feeding methods. Each pond had a surface area of 1000 m^2 and was stocked with 50,000 grey mullet seeds for seven months. In the first treatment (T1), both organic fertilizer (70 kg ha\week) and aquafeed were used, with a changing daily feeding rate according to water temperatures (feeding rate of 5% in the first month, 3% in the second month, 1% in the third to fifth months, and 2% in the sixth and seventh months). The second treatment (T2) involved inorganic fertilizer (7 kg urea + 19 kg superphosphate ha\week) along with aquafeed at the same feeding rate as T1. The third treatment (T3) solely depend on on aquafeed, with a feeding rate double that applied in T1 and T2. Feed quantity were adjusted every fifteen days based on the estimated biomass from random fish samples. The daily feed quantity was divided into two meals per day, six days a week. At the end of the trial, a total of 100 fingerlings were randomly collected from different places of each pond to perform biological analysis, measure growth performance as well as heamatological parameters and calculate the economic returns.

Water Quality Analysis

Every two weeks, water samples were collected in sterilized glass (1 liter) from each pond for the purpose of assessing water quality parameters such as temperature (°C), pH, dissolved oxygen (DO, mg/L), salinity (g/L), and ammonium concentrations. An oxygen thermometer apparatus YSI model 58 (Yellow Spring Instrument Co, OH, USA) was used to evaluate water's physicochemical properties (temperature, pH, salinity, and dissolved oxygen). In addition, ammonium concentrations were evaluated using the APHA (2012) method.

Biological Analysis

Phytoplankton and zooplankton were counted (as organisms per liter) monthly in all ponds during the rearing period. They were estimated according to sedimentation procedures reported in APHA (2000).

Hygienic Disposal Method

The Egyptian Best Management Practice (BMP) standards outlined by Dickson et al. (2016) were followed in the implementation of hygienic waste disposal and general farm biosecurity. This includes routinely cleaning the area around ponds, preventing cross-contamination between ponds, collecting and disposing of solid waste properly, and treating poultry dung safely as an organic fertilizer. By taking these precautions, the culture system was kept clean, disease risks were reduced, and national aquaculture environmental standards were met.

Environmental Conditions for Breeding

Grey mullet (*Mugil cephalus*) seeds were cultured under controlled environmental circumstances similar to semi-intensive earthen ponds in Sharkia Governorate, Egypt, during a seven-month period (October 2021-April 2022). Prior to stocking, all ponds were sun-dried, limed, and fertilized to improve sediment quality, increase natural productivity, and reduce pathogenic burden. Water levels were gradually raised to an average depth of 1.25 m, and all inlet and outflow structures were outfitted with fine-mesh screens to keep predatory fish and other species out.

Table 1. Chemical characterization, total organic carbon and proximate analysis of chicken manure (dry matter)

Element	Farm 1	Farm 2	Farm 3
Carbon %	35.77±0.06^c	37.06±0.18^b	38.68±0.11^a
Hydrogen %	4.57±0.05^b	4.54±0.13^b	5.09±0.08^a
Nitrogen %	6.98±0.09^a	6.81±0.08^a	4.62±0.08^b
Chlorine %	0.63±0.01^a	0.40±0.02^b	0.65±0.02^a
Phosphorus %	1.09±0.02^a	1.09±0.02^a	0.94±0.03^b
Sulfur %	0.05±0.01^a	0.04±0.03^b	0.05±0.01^a
Moisture	75.49±0.03^b	77.80±0.08^a	74.24±0.07^c
TOC (% dm)	34.47±0.19^b	33.10±0.11^c	36.78±0.13^a
OM (% dm)	63.80±0.22^c	70.01±0.29^a	65.67±0.08^b
Ashes (% dm)	36.48±0.06^a	29.22±0.08^c	34.23±0.04^b

Data were represented as means±standard errors. Values in the same row with different superscripts are significantly different (P<0.05). TOC: total organic carbon, OM: organic matter, dm: dry matter.

Growth Performance Parameters

Individual fish weights were measured by a digital balance at the beginning and at the end of the experiment. Growth performance parameters of five grey mullet fingerlings collected randomlfish y from different places in each pond were calculated by the following equations:

Body weight gain (g)= Final weight (g) - Initial weight (g)

Daily weight gain (DWG)= (Final body weight(g) - Initial body weight(g))/experimental period (days)

Specific growth rate (SGR)=100 x (lnW2 - lnW1) / T

Where W1 is the initial weight (g), W2 is the final weight (g), and T is the number of days in the experimental period.

Survival rate (%)=Final number of fish/ Initial number x 100

Blood Parameters

At the termination of the experiment, 5 mullet fingerlings were picked up randomly from different place in each pond and anesthetized in tricaine methane sulfonate (MS-222; 0.3 g/L) immediately before blood collection. Blood samples were collected from the caudal vein of the fish using a heparinized syringe. According to Makled et al. (2019) protocol, blood samples were pooled from each pond and divided into two parts. The first part was used to measure hemoglobin concentration (Hb), red blood cell count (RBCs), and hematocrit (Ht). While, the second part was collected in Eppendorf tubes and stored in ice after centrifugation for 2 min at 6000 rpm to isolate the blood plasma then to measure glucose level and cholesterol colorimetrically according to methods of Bayunova et al. (2002) and Henry (1964), respectively. Red blood cells (RBCs) were counted with a Bright-Line Hemocytometer (Neubauer enhanced, Germany) using Thrall et al. (2012) method. Hemoglobin (Hb) levels were measured calorimetrically, as described by Weiss & Wardrop (2011). Hematocrit (Hct) was calculated following Brown (1988) protocol. The analysis of mean corpuscular volume (MCV), mean corpuscular hemoglobulin (MCH), and mean corpuscular hemoglobin concentration (MCHC) was assessed conferring to Vazquez & Guerrero (2007) procedures.

Economic Analysis

An economic analysis was conducted to calculate the net returns and benefit-cost ratio (BCR) of the various experienced fertilization systems (Shang, 1990). The analysis depend on the fingerlings cost and the local market prices for all inputs, expressed in Egyptian pounds (EGP), then converted to US dollars (USD).

Statistical Analysis

Statistical evaluation of the experimental results was carried out using the analysis of variance one way (ANOVA) to identify the significance of differences in various parameters of grey mullet fingerlings among the treatments. Following Dytham (2011), the differences between means were assessed at P<0.05 level using the Duncan test (as a post hoc test) according to SPSS software, version 20 (SPSS, Richmond, VA, USA).

Results and Discussion

Water Quality Measurements

Preservation of good water quality is necessary for optimal development and survival of the cultured species, leading to a prolific fish production (El-Ghazaly et al, 2017). DO, temperature, pH, salinity, and ammonia are the main water quality parameters important for normal fish growth (Boyd & Tucker, 2012).

The difference in water parameters between different treatments is shown in Table 2. In the current study, water temperature varied between 15.2±0.2°C and 26.7±0.7°C where the maximum mean value was recorded during October and the minimum was found in January among treatments. The present results concur with Sunitha & Padmavathi (2013) and Eissa et al. (2024a) who mentioned that the water temperature attends the fluctuation pattern of air temperature.

The concentrations of dissolved oxygen ranged from 5.3 to 6.6, 5.3 to 6.3, and 5.2 to 6.2 mg/L in T1, T2, and T3, respectively. The increase in DO values may be due to the application of fertilizer that increased the phytoplankton production which yield most oxygen in water through photosynthesis (Chenyambuga et al., 2020). However, it was found that DO values decrease from one month to another during the trial period. This may be due to the increase in fish biomass and waste (Shaker et al., 2016). Moreover, Gogoi et al. (2015) explained that the variation in the DO concentration in aquatic bodies may be caused as the result of differences in temperature and fluctuations in photosynthetic and respiratory activities of the aquatic biomass. Regarding salinity, it was found that it fluctuated between 11.2 and 12.2 g/L among different treatments. Hence, there was no significant difference in the means of salinity, dissolved oxygen and temperature that fell in the optimum range in different management systems during the current experiment. Similar results were reported by Nasr-Allah & Nassrallah (2017), Begum et al. (2018).

Hydrogen ion concentration is the principal control parameter in aquatic environment by affecting the metabolism and other physiological processes of marine organisms (Abdelmeguid et al., 2024). The present data indicated that there was a significant increase in pH measurements (P<0.05) in T1 compared to T2 and T3 in some months (Table 2). These data may refer to the increase in photosynthetic activities as well as phytoplankton density in organic fertilizer ponds (Abdel-Wahed et al., 2018), where a higher pH value is normally associated with higher photosynthetic activities in water indicating water fertility as documented by Hujare (2008). The obtained results also concur with the data of water quality obtained by Abdel-Hakim et al. (2013).

Additionally, ammonia concentration in water ponds was significantly (P<0.05) increased in organic fertilizer ponds than other tratments along different months of the trial period. In the current study, it was found that the lowest ammonia concentration was reported inT3 (0.15±0.01) during December, while the highest one was equal to 0.31±0.01 in T1 during April but remained lower than the critical level. These findings could account for to the increase in residuals of artificial feed, fish waste and organic fertilizer which led to an increase in the organic compounds formation as well as the decomposition process by bacterial activity (Shaker et al., 2015; Chenyambuga et al., 2020). Similar findings were obtained by Shaker et al. (2016). in the earthen ponds cultivated by grey mullet and nile tilapia.

Generally, the values of water parameters recorded in the current study were within the normal range for mullet growth, which helps the fish to healthy thrive in the pond water and develop fast. Our findings also revealed that water quality is significantly impacted by pond management practices as the daily feed input and the fertilization strategy required for plankton growth as documented by Sipauba-Tavares et al. (2013).

Plankton

Plankton is the principal food of all aquatic organisms playing a vital role in the biological productivity of marine ecosystems (Terziyski et al., 2007; El-Sayed et al, 2024). The concentration of phytoplankton and zooplankton in different fed treatments ranged from 3,9895 to 223,179 org/L and 17 to 354 org/L, respectively (Table 3). Zooplankton counts were found the lowest in T3 (17±3 org/L) during January and the highest in T1 (354±35 org/L) during April. This may be attributed to the effect of cold water on photosynthetic activities and phytoplankton abundance during January. According to Bwala & Omoregie (2009), the distribution and quality of zooplankton depend on the water temperature and phytoplankton biomass. Therefore, the highest Zooplankton counts recorded during April in the present experiment may be due to the positive effect of warm temperatures on zooplankton abundance and development. In addition, the plankton population was significantly higher

Table 2. Measurments of some water quality parameters in nursery ponds during the rearing period of grey mullet under different treatments

Parameters \ Months		October	November	December	January	February	March	April
Temp. C°	T1	26.7±0.7[a]	25.5±0.4[a]	18.5±0.2[a]	15.2±0.2[a]	17.2±0.4[a]	19.5±0.4[a]	25.9±0.1[a]
	T2	26.3±0.3[a]	24.9±0.3[a]	18.2±0.3[a]	15.4±0.2[a]	17.3±0.4[a]	19.4±0.5[a]	25.6±0.1[a]
	T3	26.4±0.5[a]	25.2±0.2[a]	18.6±0.3[a]	15.3±0.5[a]	17.6±0.5[a]	19.6±0.4[a]	25.8±0.1[a]
DO mg/L	T1	6.6±0.2[a]	6.3±0.2[a]	6.1±0.2[a]	5.7±0.1[a]	5.5±0.1[a]	5.3±0.1[a]	5.6±0.1[a]
	T2	6.3±0.3[a]	6.3±0.2[a]	6.1±0.3[a]	5.6±0.1[a]	5.4±0.1[a]	5.3±0.1[a]	5.6±0.1[a]
	T3	6.2±0.2[a]	6.1±0.3[a]	6.1±0.1[a]	5.6±0.1[a]	5.9±0.1[a]	5.2±0.1[a]	5.7±0.1[a]
pH	T1	8.7±0.1[a]	9.0±0.1[a]	8.9±0.1[a]	8.6±0.1[a]	9.0±0.1[a]	9.1±0.1[a]	9.1±0.1[a]
	T2	8.5±0.1[a]	8.7±0.3[a]	8.6±0.1[b]	8.4±0.3[b]	8.8±0.1[a]	8.9±0.1[b]	9.0±0.1[a]
	T3	8.6±0.1[a]	8.8±0.2[a]	8.5±0.1[b]	8.4±0.1[b]	8.9±0.1[a]	8.9±0.1[b]	9.0±0.1[a]
Salinity g/L	T1	11.2±0.03[a]	12.2±0.03[a]	11.4±0.05[a]	11.3±0.07[a]	11.6±0.07[a]	11.9±0.08[a]	11.6±0.06[a]
	T2	11.2±0.03[a]	12.2±0.03[a]	11.4±0.07[a]	11.8±0.08[a]	11.4±0.05[a]	11.7±0.04[a]	11.7±0.05[a]
	T3	11.2±0.03[a]	12.2±0.03[a]	11.4±0.06[a]	11.4±0.05[a]	11.3±0.08[a]	11.8±0.07[a]	11.7±0.07[a]
Ammonia mg/L	T1	0.29±0.03[a]	0.30±0.03[a]	0.25±0.03[a]	0.28±0.02[a]	0.29±0.02[a]	0.30±0.02[a]	0.31±0.01[a]
	T2	0.21±0.02[b]	0.24±0.01[b]	0.20±0.02[b]	0.24±0.01[b]	0.25±0.01[b]	0.26±0.01[b]	0.27±0.02[b]
	T3	0.16±0.02[c]	0.19±0.01[c]	0.15±0.01[c]	0.19±0.01[c]	0.21±0.01[c]	0.22±0.01[c]	0.24±0.01[b]

Data were represented as means±standard errors. Means within the same row with different superscript letters are significantly different at P<0.05.

Table 3. The abundance of zooplankton and phytoplankton (org./l) in earthen ponds water during the rearing period of grey mullet under different treatments

Treatments	T1		T2		T3	
Months \ Phytoplankton	Zooplankton	Phytoplankton	Zooplankton	Phytoplankton	Zooplankton	Phytoplankton
October	265±23.0[a]	195174±10328[a]	144±15.0[b]	152318±2130[b]	54±7.0[c]	78143±1231[c]
November	230±19.0[a]	146213±10908[a]	119±12.0[b]	103165±1124[b]	43±9.0[c]	63265±1078[c]
December	211±17.0[a]	115713±10341[a]	98±13.0[b]	96728±1117[b]	32±6.0[c]	46578±1099[c]
January	159±19.0[a]	101215±12031[a]	76±11.0[b]	99219±897[a]	17±3.0[c]	39895±978[c]
February	245±22.0[a]	120612±10326[a]	113±17.0[b]	102378±1232[b]	49±8.0[c]	40346±1133[c]
March	305±32.0[a]	213654±12088[a]	187±2.01[b]	155432±5154[b]	57±9.0[c]	42923±1114[c]
April	354±35.0[a]	223179±14023[a]	213±25.0[b]	173782±7315[a]	63±8.0[c]	6541±1265[b]

Data were represented as means±standard errors. Means within the same row with different superscript letters are significantly different at P<0.05.

(P<0.05) in T1 than its corresponding in T2 and T3. This high population density is attributed to the presence of organic fertilizer (chicken manure) which is known as a high source of nitrogen and phosphorus to maximize the plankton production (Abd El-Hamed, 2014; Pathak et al., 2019). Poultry manure is admired as the best organic fertilizer used in a widespread technique in fish ponds for enhancing natural food abundance. Current findings are in agreement with the results of Hossain et al. (2006) who stated that the highest plankton abundance was documented in ponds getting chicken manure. Our results were also demonstrated by Elnady et al. (2010). Furthermore, the present findings indicated that the optimum water quality parameters in addition to the chicken manure provided a favorable environment for plankton production. Our findings are consistent with the the study of Das et al. (2020) who confirmed that higher survival rate and growth perfprmance in fish seed nursing were achieved by applying favourable water quality, optimal doses of poultry manure and optimum density of plankton population. Hence, natural food abundance in fish ponds reduces the requirements for artificial feed inputs. This will lead to a reduction in feeding costs and an improvement in farm revenues.

Growth Performance and Survival Rate

The growth performance and survival rate of grey mullet fries under the three experimental treatments are represented in Table 4 and Figure 1. There were significant variations (P<0.05) in all studied growth performance parameters among different treatments. The fish nursery under T1 recorded the highest growth performance, while the lowest value was recorded in those reared under T3. These results also indicated that *Mugil cephalus* reared in T1 displayed the highest values of final body weight, wet gain, and daily gain weight rate corresponding to 10.4±0.31g, 10.05±0.3 g, and 0.0480±0014g, respectively than their corresponding in other treatments. A similar trend has also been reported with regard to specific growth rate (SGR) values. Similar observations were also reported in carp, mullet and tilapia (Hussein & Abdel-Hakim 2003). The increase in T1 may be due to the high production of natural food organisms (phytoplankton and zooplankton) by organic fertilization. This, in turn, enhances higher fish growth as a result of an increase in the natural food availability (Chenyambuga et al., 2020). Moreover, Elnady et al. (2010) reported that fish growth is effectively linked with the increase in phytoplankton and zooplankton productivity due to fertilization.

The difference in survival rate at the completion of the rearing period was found to be significant (P<0.05) among all treatments. The present data indicated that the average survival rate was 60.00±1.8, 57.00±1.3, and 55±1.2% in T1, T2, and T3, respectively. Hence, the survival rate of T1 was more than T2 and T3 by 3% and 5%, respectively. The lowest survival rate percentage noted in T3 may be attributed to the inadequate natural fish food organisms**.** These results are in agreement with the survival data of green back mullet (*Chelon subviridis*) fries reared in nursery ponds obtained by Yasmin et al. (2016).

Table 4. Growth performance parameters and survival rate of grey mullet reared under different treatments

Parameters	Treatments		
	T1	T2	T3
Initial weight (g)	0.35±0. 02	0.35±0. 01	0.35±0. 04
Final weight (g)	10.4±0.31^{a}	7.4±0.25^{b}	6.7±0.1^{b}
Wet gain (g)	10.05±0.3^{a}	7.05±0.3^{b}	6.35±0.06^{b}
Daily weight gain (g)	0.048±0.0014^{a}	0.034±0.0011^{b}	0.030±0.0003^{b}
weight gain rate (g)	2871.4±87.3^{a}	2014.3±71.9^{b}	1814.3±16.5^{b}
Specific growth rate (%/day)	1.6±0.015^{a}	1.43±0.017^{b}	1.38±0.004^{c}
Survival (%)	60.0±1.8^{a}	57.0±1.3^{b}	55.0±1.2^{c}

Data were represented as means±standard errors. Means within the same row with different superscript letters are significantly different at P<0.05.

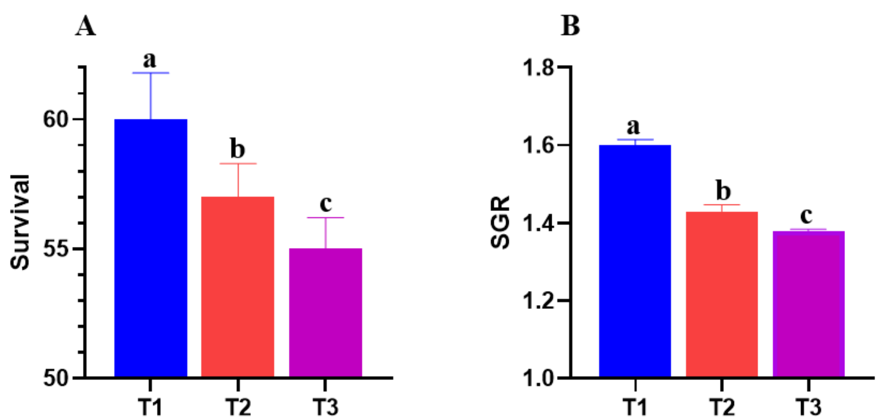

Figure 1. Survival and specific growth rate (SGR) of grey mullet in different treatments.

Therfore, the significantly higher survival rate and growth parameters in T1 than in T2 and T3 indicated that they were affected by fertilization. However, organic fertilization produced bigger fingerlings with better survival rate caused by the natural food abundance. This also indicate that the inorganic fertilization and artificial food did not meeting the biological needs of growing fish (Biswas et al., 2017). Similar observations were also mentioned by Abd El-All (2001). Moreover, Mou et al. (2013) and Kour et al. (2015) reported that organic fertilizer was more effective for rearing fish than inorganic fertilizer or a mixture of organic and inorganic fertilizers. According to Saad et al. (2014) and Claude (2018), chicken manure is considered to be the best fertilizer because it contains more content of phosphorus and nitrogen. Thus, it helps in maintaining natural food production in fish ponds and improvement of the biological condition of pond water by improving growth performance, survival rate, and fish production. Jha et al. (2007) also informed that chicken manure triggers more phytoplankton production in the fish ponds than any other chemical fertilizer as it raises the concentration of pH, dissolved oxygen and total phosphates (Ponce-Palafox et al., 2010).

Haematological Parameters

Hematological and biochemical parameters of serum are utilized to evaluate the health of marine organisms, their ecosystems as well as the quality of fish diet (Loghmannia et al., 2015; Hassanien et al., 2017; Eissa et al., 2024b). The values of the blood parameters in different treatments are presented in Table 5 and Figure 2. During the rearing period, hemoglobin level, erythrocytic count and hematocrit percentage in different fingerlings were highly significantly ($P<0.05$) different, showing an increase in T1 (7.7 g/dl, 2.323, and 16.94%) followed by T2 (7. 0 g/dl, 2.212 and 15.84%) and T3 (6.8 g/dl, 2.199 and 15.52%), respectively. Similar trends were observed in the values of MCV, MCH, and MCHC among the treatments (Figure 2). Briefly, T1 recorded the highest MCV, MCH and MCMH compared to T2 and T3. In addition, a significant increase in RBCs and Ht levels was observed coupled with a reduction in MCV, MCH and MCHC values. Our findings concur with the heamatological results of lathead grey mullet (*Mugil cephalus*) studied by Parrino et al. (2018). The obtained results are also similar to the studies of Yola & Adikwu (2017) and Kumar et al. (2019) who observed higher RBC count and hemoglobin levels in poultry manure. This increase can be due to good health conditions and the appropriate age of the fish. In addition, Talpur & Ikhwanuddin (2012) explained that the hemoglobin content in the blood serves as an oxygen transport component to all body tissues. Accordingly, the rises in its contents signify a greater oxygen supply to the fish and, consequently, improve its health status.

On the other hand, glucose values were lower in T2 and T3 than their corresponding in T1 (Table 5). The maximum cholesterol mean was found in T1 (82.3 mg/dl) and the minimum was noted in T2 (79.4 mg/dl). No statistical difference was found in the level of glucose and cholesterol. Similar results were recorded in carp, mullet and nile tilapia (Abdel-Hakim et al., 2013). Variations in blood parameters depend upon the species, aquatic biotope, age and health of fish (Fazio et al., 2016). Quality of water, oxygen, temperature, and salinity are also directly reflected in blood parameters (Sheikh & Ahmed, 2016), as well as stocking density and basic ecological factors such as feeding regime (Ferri et al., 2011).

The variation in the values of the studied blood parameters of grey mullet fingerlings obtained in the present experiment explains the effective role of the organic manure in the pond water. Therefore, there is a need to fertilize ponds with organic fertilization to increase fish nutrients and to maintain the ponds in a good condition.

Economic Returns

The cost-benefit analysis for mullets fingerlings in nursery ponds revealed pronounced variations in benefits and costs, as illustrated in Table 6. Total costs were the highest in the third treatment (T3), amounting to 7,463 USD, compared to T2 and T1, which incurred 7,352 USD and 7,296 USD, respectively. Moreover, T1 yielded the highest net profit of 3,077 USD, while T2 and T3 achieved profits of 2,383 USD and 1,962 USD, respectively. Furthermore, the Benefit-Cost Ratio was 1.42 for T1, 1,962 for T2, and 1.26 for T3.

The current results indicate that combining organic fertilizers with aquafeed yields higher economic returns in mullet nurseries compared to using inorganic fertilizers with aquafeed or relying solely on aquafeed. This data consistent with the findings of Shaker et al. (2016), who proved that organic fertilizer treatment led to an increase in economic returns. This may be attributed to readily available dissolution and increased nitrogen and phosphorus nutrients for primary

Table 5. Assessment of some blood parameters of grey mullet under different treatments

Parameters \ Treatments	T1	T2	T3
Hb (g/dl)	7.7±0.1^{b}	7.0±0.2^{a}	6.8±0.2^{a}
RBCs (x10^{6}/ml)	2.323±0.012^{c}	2.212±0.011^{b}	2.199±0.005^{a}
Ht (%)	16.94±0.21^{c}	15.84±0.12^{b}	15.52±0.14^{a}
Glucose (mg/dl)	98.3±1.5^{b}	94.2±1.1^{a}	90.4±4.2^{a}
Cholesterol (mg/dl|)	82.3±0.5^{c}	79.4±0.2^{a}	78.9±1.0^{a}

Data were represented as means±standard errors. Means within the same row with different superscript letters are significantly different at $P<0.05$.

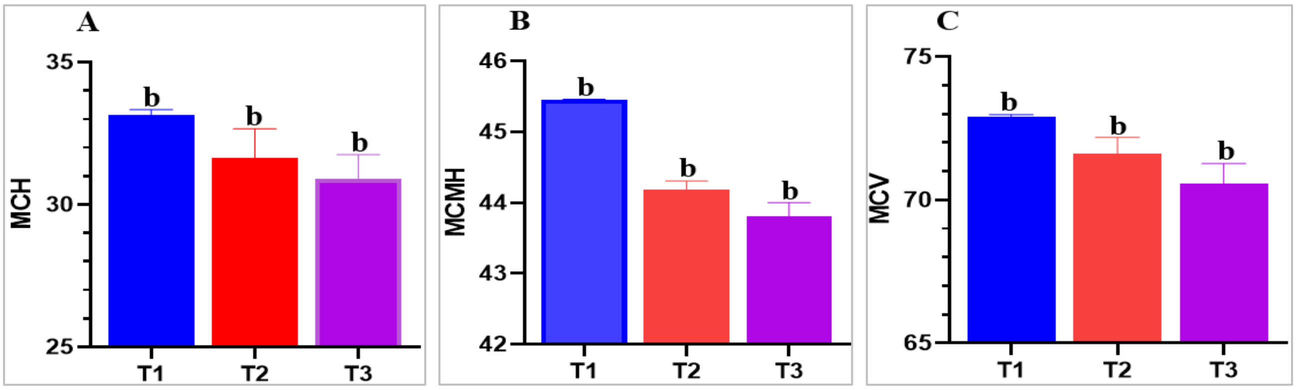

Figure 2. Status of some blood indices (A. MCH, B. MCMH, C. MCV) of grey mullet in different treatments.

Table 6. Cost-benefit analysis for grey mullet in nursery ponds (1000 m^2) during the experimental period among different treatments

Item (USD*)	Treatments		
	T1	T2	T3
Cost			
Prepare the pond	129.39	129.39	129.39
Seeds	5639.10	5639.10	5639.10
Feeds	189.45	189.45	378.89
Fertilizers			
Organic	22.38	0.00	0.00
Chemical	0.00	78.20	0.00
Labour	877.19	877.19	877.19
Land use	250.63	250.63	250.63
Energy	187.97	187.97	187.97
Total cost	7296.10	7351.91	7463.16
Total Benefit	10372.81	9735.28	9425.13
Net benefit	3076.71	2383.36	1961.96
Benefit-cost ratio	1.42	1.32	1.26

*The average exchange rate of the USD to the Egyptian pound is 15.96 EGP.

productivity leading to a decrease in production costs (Nasrallah & Nasrallah, 2017). Additionally, Hebicha et al. (2013) reported that the presence of natural food in pond waters reduces fish demand for artificial feeds, leading to a decline in production costs and an increase in the farm income. Therefore, a feed management strategy is crucial for achieving farmers profitability and reducing nutrient inputs, thus providing a friendly environment for aquaculture (George et al., 2016).

Conclusion

The current study concluded that the nutritional feeding strategy by combining organic fertilizers with aquafeed achieved a higher significant impact than that comprising inorganic fertilizers with aquafeed or aquafeed only in nursery grey mullet ponds, in terms of improving growth and survival of mullet seeds collected from the wild, providing favourable water quality, increasing the productivity of phytoplankton and zooplankton, intensifying fingerlings yield, decreasing production costs and increasing the income revenue for fish farmers.

Ethical Statement

The present research was conducted with prior animal ethical approval of Zagazig University Animal Ethics Committee (ZU-IACUC/2/F/149/2025).

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Author Contribution

Norhan H. Ahmed and El-Sayed Hemdan Eissa; Conceptualization, Writing -review and editing, Project Administration, Resources, Supervision, Formal Analysis, Investigation, Methodology, Writing -original draft.

Sara F. Ghanem, Moaheda E.H. Eissa, Mohammad Bodrul Munir and Nadia Nazmy B. Abd El-Hamed; Data Curation, Visualization, Investigation, Writing -review and editing, Writing - review and editing.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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