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NILE TILAPIA (*Oreochromis niloticus*) SEED PRODUCTION AND GROWTH PERFORMANCE OF FRY AND GROWER BROODSTOCKS IN NORTHWEST ETHIOPIA

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ABSTRACT: Small-scale Nile Tilapia (*Oreochromis niloticus*) fry production is essential for improving seed availability and supporting sustainable aquaculture. This study evaluated the biological performance and economic feasibility of Nile tilapia fry production in earthen ponds using a locally formulated diet under small-scale farming conditions in Ethiopia. Thirty-three broodstock fish (11 males and 22 females) collected from the Geray Reservoir region were stocked in a 100 m² earthen pond at a male-to-female ratio of 1:2 and fed a locally formulated diet containing 35% crude protein at 3% of body weight per day. The diet consisted of fish meal (38.1%), soybean meal (38.1%), and wheat bran (24.0%), offered twice daily. Male brood stocks showed significantly greater growth performance than females ($P < 0.001$). Each spawning cycle produced approximately 3,300 fry, and broodstocks spawned an average of eight times annually, yielding about 1,200 fry per female and an estimated annual production of 26,400 fingerlings. Fry reared in the best-performing on-farm pond (researcher) achieved significantly greater final weight, final length, and daily growth rate than those reared at the other sites (farmers) ($P < 0.001$), while survival remained consistently high (98.75–100%) with no significant differences among sites. In water quality, no significant differences among sites for temperature, dissolved oxygen, pH, total dissolved solids and ammonia ($P > 0.05$), although electrical conductivity differed significantly ($P < 0.001$). Total feed consumption was 251.16 kg, corresponding to a total feed cost of US$105.94. The selling price was US$0.079 per fingerling. The production system generated positive economic returns. These findings demonstrate that earthen-pond-based Nile tilapia fry production using locally formulated feeds is a technically feasible and economically viable approach for increasing the availability of quality fingerlings. The technology has strong potential for dissemination through Farmers Training Centers to support sustainable aquaculture development, fisheries enhancement, and improved rural livelihoods in Ethiopia.

Keywords: Economic feasibility, Ethiopia, Formulated feed, Fry production, Growth performance, *Oreochromis niloticus*

INTRODUCTION

Nile tilapia (*Oreochromis niloticus*) is one of the most important freshwater fish species in global aquaculture owing to its rapid growth, adaptability to diverse environmental conditions, efficient feed utilization, high consumer acceptance, and excellent reproductive capacity. It is the second most widely farmed aquatic species after carps and is cultured in more than 135 countries, accounting for over 70% of global tilapia production (El-Sayed, 2020; FAO, 2023; Fitzsimmons and Feldman, 2025). Despite being the native home of Nile tilapia, Africa contributes only a small proportion of global aquaculture production, indicating substantial opportunities to improve fish production through enhanced seed availability and better hatchery management. The reproductive characteristics of Nile tilapia make the species particularly suitable for hatchery production. Female Nile tilapias are maternal mouth brooders that incubate fertilized eggs and larvae in the buccal cavity until the fry are sufficiently developed to survive independently (Mansour, 2001; El-Sayed and Fitzsimmons, 2023). Under favorable environmental conditions, females can spawn approximately every 30 days, enabling continuous fry production throughout the year. Nevertheless, realizing this biological potential depends on effective brood stock management, including the selection of healthy broodstocks, balanced nutrition, appropriate stocking density, and suitable male-to-female ratios (El-Sayed, 2006).

Despite the high reproductive capacity of Nile tilapia, the availability of quality fingerlings remains one of the major constraints limiting aquaculture expansion in many African countries. Poor broodstocks management, inadequate hatchery infrastructure, inconsistent seed quality, and low fry survival continue to reduce hatchery productivity (Bhujel, 2011; Hasimuna et al., 2019). Consequently, many fish farmers still rely on fry collected from natural water bodies, a practice that is unreliable, threatens genetic quality, poses biosecurity risks, and is environmentally unsustainable (Bondad-Reantaso, 2007). Strengthening small-scale hatchery production is therefore essential for ensuring a reliable and sustainable supply of quality seed. Feed is another major factor influencing aquaculture productivity and profitability. Feed

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commonly accounts for more than half of total production costs, while commercial diets remain expensive and inaccessible to many small-scale farmers (Hasimuna et al., 2019; Das and Govindasamy, 2021). Consequently, locally formulated feeds prepared from readily available ingredients have attracted increasing interest as cost-effective alternatives capable of supporting satisfactory growth and reproductive performance. Providing nutritionally balanced diets with adequate protein and energy is fundamental for improving broodstocks condition, fry survival, and fingerling growth (Spinelli 2014; Engdaw and Geremew, 2024). Across sub-Saharan Africa, earthen ponds remain the dominant aquaculture production system because they require relatively low investment and are well suited to smallholder farming systems (Satia, 2017, MafwilaKinkelaet al., 2019; Kwikiriza et al., 2026). Semi-intensive pond culture offers an effective balance between affordability and productivity by providing better environmental management, improved feeding efficiency, and higher fry survival than extensive systems (Bhujel, 2011; Li and Yakupitiyage, 2023).

Ethiopia has abundant freshwater resources, including lakes, reservoirs, rivers, and dams, providing considerable potential for aquaculture development. Nevertheless, the country's aquaculture sector remains underdeveloped compared with neighboring East African countries because of limited hatchery capacity, inadequate availability of quality fingerlings, high feed costs, and shortages of technical expertise (MOLF, 2018; FAO, 2023). Although government hatchery centers have been established in several regions, current seed production remains insufficient to satisfy the increasing demand from fish farmers. Regional production records further demonstrate the limited capacity of existing hatcheries to supply quality tilapia seed across the country (Table 1).

Table 1 - Regional Nile tilapia seed production in Ethiopia during three consecutive production years (2020/21–2022/23).

Year	Amhara	Oromia	Sidama	SNNP	Sebeta	Sub-total
2020/21	380,000	76,550	49,840	36,000	1,029,150	1,571,540
2021/22	383,262	41,082	53,900	60,000	1,016,850	1,555,094
2022/23	406,225	72,300	69,000	68,000	1,049,800	1,665,325
Annual total	1,169,487	189,932	172,740	164,000	3,095,800	4,791,959

Source: (FAMP, 2024). SNNP= Southern Nations, Nationalities, and Peoples

Improving seed quality remains a major constraint to aquaculture development in Africa. Despite increasing seed production, the availability of genetically improved broodstock and high-quality fingerlings remains limited due to poor broodstocks management, genetic deterioration, inadequate hatchery practices, and weak quality-control systems (Brummett, 2007; Adewumi, 2015; Kajungiro et al., 2019). In Ethiopia, aquaculture still depends largely on fry and fingerlings from natural water bodies, which often have unknown genetic backgrounds and variable growth performance. The use of mixed-sex fingerlings further reduces productivity through uncontrolled reproduction, feed competition, and overcrowding. Reliable hatchery technologies are therefore essential for producing healthy, genetically sound fingerlings and supporting both aquaculture development and fisheries enhancement. However, limited information is available on the biological performance and economic feasibility of small-scale Nile tilapia seed production using locally formulated feeds under Ethiopian conditions. This study evaluated the effects of locally formulated diets on Nile tilapia bloodstocks and fingerling performance, assessed fry production in earthen ponds, and examined the economic feasibility of small-scale seed production systems. The findings aim to support affordable hatchery development, improve quality seed availability, and promote sustainable aquaculture growth in Ethiopia.

MATERIALS AND METHODS

Study Area and Experimental Design

The study area was found at JabiTehnan Districts in the West and North Gojjam Zone of the Amhara Region, Northwest Ethiopia. A map of the study area is presented (Figure 1). West Gojjam zone has a total population of 2,789,106 people, of whom 1,400,635 are men and 1,388,471 women. Source (CSA, 2008).This Zone has a total surface area of 13,311.94 square kilometers (Figure 1).

Experimental design

Figure 1 showing the main research activities and experimental procedures carried out in the study. The experiment was conducted in BakeleKebele, a rural area within the FinoteSelam Town Administration, located in the Jabitehnan District of northwestern Ethiopia. The area is characterized by a moderately warm climate, with a mean annual temperature of approximately 20°C. The experimental pond was manually excavated and disinfected with calcium oxide (CaO) to provide a safe culture environment and maintain water quality. Following a 15-days stabilization period after CaO application, the pond was prepared for the experiment. Soybean grains were soaked in water for 5–7 h at a water temperature of 25 °C before grinding into soybean milk. One kilogram of soybeans was mixed with 15–20 kg of water. After the soybean milk was prepared, it was sprayed onto the pond water to maintain stable water quality and promote

good fish survival and growth. Feed processing and formulation were completed before the bloodstocks were stocked in the experimental pond.

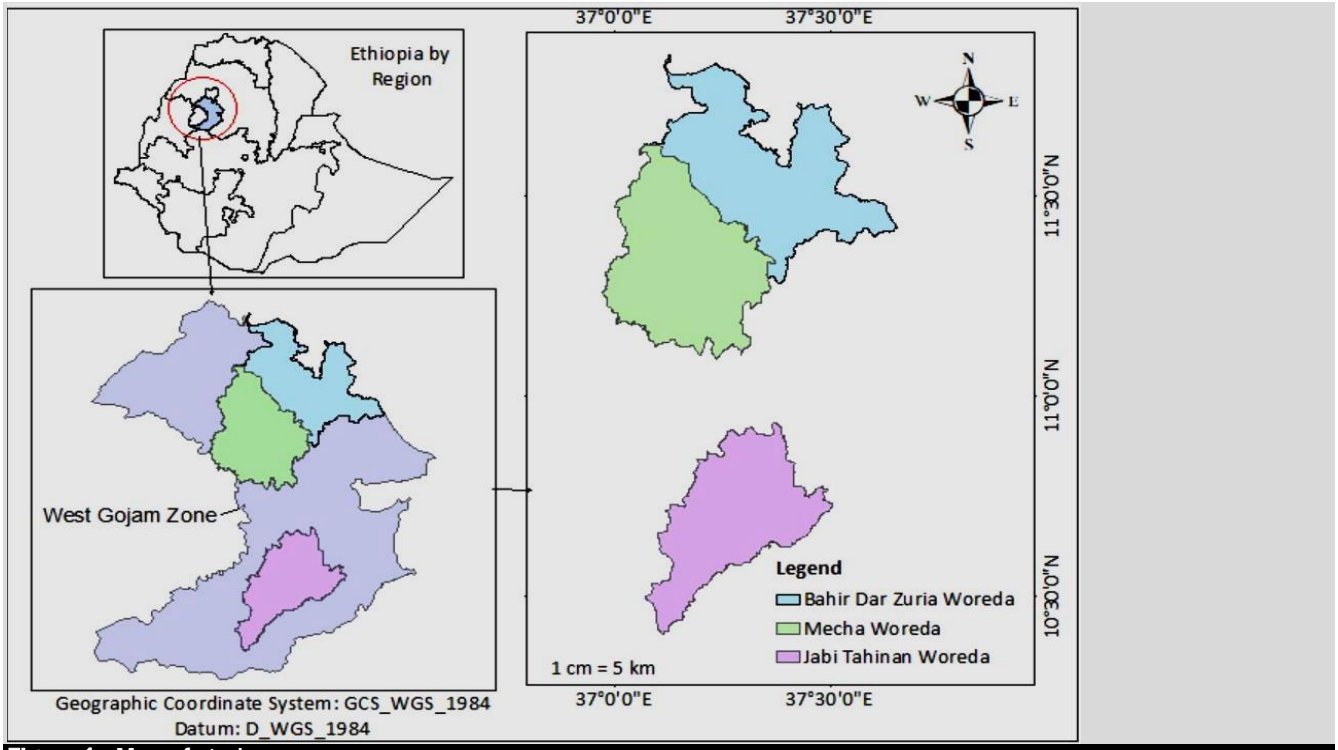

Figure 1 - Map of study area.

Brood stocks collection and management

Permission to collect Nile tilapia broodstock was obtained from the Geray Reservoir Fishers' Cooperative. Healthy broodstock were captured by experienced local fishers from Geray Reservoir, located approximately 3 km from the experimental site. Sex identification was performed by examining the genital papilla and secondary sexual characteristics following (Zaijie and Jianjun, 2016). Males were identified by a single urogenital opening, longer, dorsal and anal fins extending toward the middle of the caudal fin, and generally larger body size than females of similar age (Basiao, 1981). Although manual sex identification may result in an error rate of 3–10% (Hickling, 1963), it remains the standard procedure for broodstocks selection. A total of 33 healthy broodstocks, comprising 11 males (216–300g) and 22 females (166–254 g), were selected based on body weight, total length, and overall health condition. Fish were stocked in the earthen pond at a male-to-female ratio of 1:2, which is widely recommended for efficient spawning and fry production.

Feed formulation and feeding management

A locally formulated diet containing approximately 35% crude protein was prepared using fish meal, soybean meal, and wheat bran (Table 2). Fish meal was produced from fish-processing by products collected from Geray Reservoir, whereas soybean meal and wheat bran were purchased from local agro-processing factories. The proximate composition of individual ingredients was determined according to the standard methods of the Association of Official Analytical Chemists (AOAC, 2019). Diet formulation was performed using the Pearson square method to satisfy the nutritional requirements of Nile tilapia broodstocks and fingerlings. Feed ingredients were finely ground, thoroughly mixed, lightly moistened with water, and pellet using a meat grinder. Pellets measuring 3–4 mm were prepared for broodstocks, whereas pellets of 1.0–1.5 mm were produced for fry during the first month and 1.5–2.0 mm thereafter. Pellets were shade-dried and stored in a cool, dry place until use. Broodstocks and fingerlings were fed daily at 3% of their live body weight for 90 days. The daily feed ration was divided into two meals, with 60% provided at 8:30 AM and 40% provided between 9:30 and 10:30 PM. Feed allowances were adjusted every two weeks according to changes in fish biomass.

Table 2 - Ingredient composition and estimated crude protein contribution of the on-farm formulated feed

Feed ingredients	Inclusion level (%)	Contribution to crude protein (%)
Fish meal	38.1	22.3
Soybean meal	38.1	10.8
Wheat bran	24	1.9
Total	100	35

Fish sampling of growth and water quality measurements

Fish were sampled at two-week intervals using a scoop net. Handling time was minimized to reduce stress. Individual body weight was measured to the nearest 0.1 g using a digital balance, while total length was recorded to the nearest 0.1cm using a measuring board. After measurement, all fish were immediately returned to the culture pond. Water quality was monitored weekly throughout the experimental period. Temperature, dissolved oxygen, pH, electrical conductivity, and total dissolved solids were measured in both the morning and afternoon using a portable multi-parameter water-quality meter. Total ammonia concentration was determined separately using standard analytical procedures to ensure that water quality remained within the acceptable range for Nile tilapia culture.

Quality brood stocks and fingerlings remain major constraints to aquaculture development in Africa because of poor broodstock management, genetic deterioration, inconsistent hatchery practices, and inadequate quality-control systems (Brummett, 2007; Adewumi, 2015; Kajungiroet al., 2019). In Ethiopia, fish farming still depends largely on fry collected from natural water bodies, which often have unknown genetic backgrounds and variable growth performance. Furthermore, mixed-sex fingerlings frequently result in uncontrolled reproduction and reduced production efficiency. This study was therefore designed to evaluate the biological performance and economic feasibility of small-scale Nile tilapia fry production in earthen ponds using a locally formulated feed under Ethiopian farming conditions.

Growth parameters

Fish growth performance was evaluated using weight gain (WG), daily growth rate (DGR) specific growth rate (SGR), feed conversion ratio (FCR) and survival rate (SR) were calculated as standard equations (Adebayo et al., 2004). Growth parameters were calculate by the following formula:

Weight Gain (WG) is the difference between the final body weight and the initial body weight of fish over a period of time expressed in percentage.

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

Daily weight gain (g/fish/day) = Final weight (g) – Initial weight (g)/culture period (days)

$$\text{Survival rate (\%)} = \frac{\text{Number of fish harvested}}{\text{Number of fish stocked)}} * 100$$

Specific growth rate: It refers to the instantaneous change in fish weight expressed as the percentage increase in body weight per day over any given time interval. It was determined by taking natural logarithms of body weight and expressing growth as % per day-1 (Ricker, 1979, Márquez et al., 2024)

$$\text{SRG \%} = \frac{(\text{Ln wf-Ln Iw}) * 100}{\text{Number of day (t)}}$$

Feed conversion ratio (FCR)

The feed conversion ratio is defined as the ratio of dry feed fed per unit live weight gain and serves as a measure of the diet's efficiency. FCR will be calculated by the following formula (Hepher, 1988; Williams, 2009).

$$\text{FCR} = \frac{\text{Total feed fed for fish}}{\text{Live weight gain by fish}}$$

The main problem here is that FCR is usually given in wet weights of both food and weight gain. Some foods, such as plants and or natural food, contain much more moisture than others, such as grains or dry pellets. This may cause bias to be unnecessarily related to the nutrient content (Shoko et al., 2016; FAO, 2024).

$$\text{Survival rate (SR,\%)} = \left(\frac{\text{Number of live fish}}{\text{Number of hatched fish}}\right) * 100$$

Protein efficiency ratio

The protein efficiency ratio is defined as the ratio between the weight gain of fish and the amount of protein fed (De Silva and Anders, 1995; Webster and Lim, 2002).

$$\text{Protein efficiency Ratio (PER)} = \frac{\text{Weight gain of fish (g)}}{\text{Total crude protein intake (g)}}$$

Data analysis

The data were first subjected to a test of homogeneity and normality of variance, followed by a one-way analysis of variance (ANOVA) to evaluate differences in growth response and survival rates stocked with experimental fish feed formulated with different diets. To determine the pair wise comparison between formulated diets, the Tukey-HSD post-hoc test ($P < 0.05$) was used. The mean value of each water quality parameter was taken and compared between seasons. All statistical analyses were conducted using Microsoft Excel and IBM SPSS Statistics. Results are presented as mean± standard error (SE).

RESULTS AND DISCUSSION

Fry production, feed management, and growth performance

Small-scale Nile tilapia (*Oreochromis niloticus*) fry production was successfully carried out in a 100 m² earthen pond. During a single 90-day spawning cycle, 22 female and 11 male broodstocks produced approximately 3,300 fries. The fries were subsequently reared to the fingerling stage over an additional 90 days, reaching a mean final body weight of 39.13 ± 0.02 g and a mean total length of 14.6 cm (Table 3). A total of 50 model farmers participated in the fry production activities and received practical training in pond-based seed production. Feed pellet size was adjusted according to the developmental stage of the fish. Pellets measuring 1–2 mm in diameter were used during the early fry stage, followed by 2–3 mm pellets during the fingerling stage and 3–4 mm pellets for brood stocks. The ingredient composition, inclusion levels, and protein contribution of the on-farm formulated diets are presented in Table 2. The growth performance of brood stocks and fingerlings is summarized in Tables 3 and 4, respectively. Male brood stocks showed greater final body weight and higher daily growth rates than female brood stocks throughout the experimental period (Table 3). Fingerlings reared under the on-farm feeding regime revealed consistent growth, attaining a mean final body weight of 39.13 ± 0.02 g and a mean total length of 14.6 after 90 days of culture (Table 4). Survival and seed production were successfully maintained throughout the study using the on-farm formulated diets under earthen pond conditions.

The production potential and estimated annual revenue of Nile tilapia fry under earthen pond conditions using a male-to-female broodstocks ratio of 1:2. A total of 33 broodstocks, consisting of 11 males and 22 females, were organized into 11 breeding groups. On average, each female broodstock produced 150 fry per spawning, and with eight spawning cycles per year, the system generated approximately 1,200 fry per group. This resulted in a total annual production of 26,400 fry/fingerlings. Assuming a market price of US$0.079 per fingerling, the estimated annual revenue US$2085.9, indicating the strong economic potential of Nile tilapia seed production under the studied management conditions (Table5)

Table 3 - Growth performance of male and female grower brood stock of Nile tilapia (*Oreochromis niloticus*) during the experimental period.

Parameters	Males	Females	P-value
Mean initial weight (g)	215.55^{a}	166.41^{b}	0.001
Mean final weight (g)	413.00^{a}	257.05^{b}	0.001
Mean initial length (cm)	16.00^{a}	15.20^{a}	0.001
Mean final length (cm)	30.00^{a}	24.60^{b}	0.001
Body weight gain (g)	271.90^{a}	90.64^{b}	0.001
Daily growth rate	1.65^{a}	0.76^{b}	0.001
Specific growth rate	4.41	3.76^{b}	0.001
Feed conversion ratio	0.14^{a}	0.80^{b}	0.001
Survival rate %	100	100	1.000

Table 4 - Growth performance of Nile tilapia (*Oreochromis niloticus*) fry reared under on-farm conditions mean +SE

Parameters	Site1	Site2	Site3	P-value
Mean initial length (cm)	0.02±0.00	0.02±0.00	0.02±0.00	1.000
Mean final length (cm)	14.60±0.0^{a}	8.17±0.01^{b}	8.17±0.01^{b}	0.0001
Stocking density (fish m^{-2})	8	8	17	
Mean initial weight (g)	0.02±0.0	0.02±0.0	1.12±0.0	1.000
Mean final weight (g)	39.13±0.05^{a}	27.01±0.03^{b}	27.01±0.03^{b}	0.0001
Body weight gain(g)	39.11^{a}	26.99^{b}	26.99^{b}	0.001
Daily growth rates	0.43^{a}	0.30^{b}	0.30^{b}	0.001
Specific growth rates (%)	1.20^{a}	0.80^{b}	0.80^{b}	0.001
Survival rates (%)	98.75	99.25	100	

Site 1 and Site 2 = Farmer's pond 1 and pond 2; and Site 3 = Research pond

Table 5 - Nile tilapia fry production potential and estimated annual revenue under earthen pond conditions

MFSR	NG	NoFBS	TLBS	MFPB	SP/Y	TFP	TLFPY	PPF US$	TR (US$)
1:2	11	22	33	150	8	1,200	26400	0.079	2085.6

MFSR= Male and Female sex ratio, NG = Number of groups, NO FBS = Number of females brood stocks, TLBS =Total brood stocks, MFPPB = Mean fry production per brood stock, SP Y=Spawning per year, TFP = Total fry/fingerlings production, TLFPY = Total fry production per year, PPF =Price per fingerling in US$, and TR = Total revenue in fry selling per year.

During the experimental period, water temperature ranged from 20.8–27.4 °C, and the optimum temperature for best hatching and survival rates ranged from 25–32 °C. The decrease in water temperature below 22 °C in subtropical areas can lead to a delay or decrease in seed production, as had been reported for Nile tilapia in Vietnam (Dan and Little, 2000), and Egypt (Nasr-Allah et al., 2014). The water quality parameters were aligned with international standards and suitable for the growth of fish (Table 6). The temperature remained almost the same across all sites (around 24°C), showing that the ponds were exposed to similar environmental and climatic conditions. This similarity suggests that temperature was not a major factor causing differences in water quality among the sites. The dissolved oxygen (DO) level was slightly lower in S3 (5.88 mg/L) compared with S1 and S2 (6.18 mg/L). This small reduction may be explained by the higher fish stocking density and the use of supplementary feed in S3. As more feed enters the pond, more organic waste is produced, encouraging microbial activity and decomposition processes that consume oxygen from the water. However, the DO level in S3 was still within a suitable range for Nile tilapia growth. The pH of S3 (8.82) was slightly lower than that of S1 and S2 (9.12). This change may be related to the greater biological activity in S3. Higher fish numbers and additional feed respiration, organic matter breakdown, and nitrification processes, which release carbon dioxide and hydrogen ions into the water, causing a slight reduction in pH.

The highest total dissolved solids (TDS: 185.5 mg/L and electrical conductivity (EC: 349.5 µS/cm) were recorded in S3, suggesting a greater accumulation of dissolved substances in the pond water. This was likely due to the combined effects of higher stocking density and formulated feed, which increased the input of nutrients, minerals, and metabolic wastes into the aquatic environment. Ammonia concentration was also slightly higher in S3 (0.16 mg/L) compared with S1 and S2 (0.12 mg/L). This increase is expected because a greater number of fish produce more metabolic waste, and uneaten feed contributes additional organic material that breaks down into ammonia. Although ammonia levels increased, they remained within an acceptable range for Nile tilapia culture, indicating that the pond environment was still suitable for fish survival. Overall, S3 represented a more productive but more demanding culture environment. The higher stocking density and feeding strategy improved nutrient availability for fish growth but also increased the pressure on water quality. In contrast, S1 and S2 maintained more stable water conditions because they received lower nutrient inputs and had a lighter biological load. These results highlight the importance of careful management, especially in intensive systems like S3, to maintain a healthy balance between fish production and water quality. Water temperature ranged from 20.8 to 27.4°C throughout the study. Dissolved oxygen varied between 5.88 and 6.18 mg L^{-1}, while ammonia remained below 0.16 mg L^{-1} (Table 6).

Table 6 - Physicochemical characteristics of hatchery water during fry production at different sites (mean ± SE)

Sites	TO	Do	pH	TDS	EC	NH_3	P-value
S1	24.13±1.94^{a}	6.18±0.87^{a}	9.12±0.18^{a}	135.5±46.48^{ab}	257.67±65.24^{b}	0.12±0.00^{a}	0.001
S2	24.10±1.89^{a}	6.18±0.87^{a}	9.12±0.1^{8a}	135.50±46.48^{ab}	257.67±65.24^{b}	0.12±0.00^{a}	0.001
S3	24.11±1.91^{a}	5.88±0.87^{a}	8.82±0.18^{a}	185.5±46.48 ^{ab}	349.50±66.68^{c}	0.16±0.00^{a}	0.001

TO: Temperature (°C); DO: Dissolved oxygen (mg/L); pH: hydrogen ion (H); TDS: Total dissolved solid(mg/L); EC: Electric conductivity (µS) and NH_3 (Ammonia); S1= Site 1, S2- Site 2 and S3= Site 3. Different superscript letters show significant difference.

DISCUSSION

The locally formulated diet used in this study, comprising of fish meal, soybean meal, and wheat bran, supported satisfactory brood stock performance, fry production, and fingerling growth under earthen pond conditions. Fish meal likely contributed highly digestible protein and essential amino acids required for reproduction and tissue growth, while soybean meal provided an accessible plant-based protein source that reduced dependence on expensive commercial ingredients (Hekmatpouret al., 2021; Nakamori, 2022). Wheat bran contributed energy and improved feed texture. It is an

important energy-contributing ingredient through its residual starch and digestible carbohydrates while also improving the physical characteristics of the diet, including pellet integrity and feed texture, thereby enhancing feed handling and stability (Sztupecki et al., 2023; Staset al., 2024).

These results demonstrate that locally available ingredients can be effectively combined to formulate nutritionally suitable diets for small-scale Nile tilapia seed production. Feed cost remains one of the greatest constraints limiting aquaculture development in developing countries. The use of locally formulated feeds in the present study reduced dependence on commercial diets while maintaining acceptable growth performance. However, economic evaluation should consider all production costs, including ingredient preparation, labor, and management inputs. The positive production output obtained under the present system indicates that on-farm feed formulation has potential to improve the economic feasibility of decentralized hatchery operations.

The reproductive performance observed in this study confirms the suitability of Nile tilapia for small-scale seed production under earthen pond conditions. The production of approximately 3,300 fry per spawning cycle from 22 female broodstock demonstrates the potential of pond-based hatchery systems to increase local seed availability. Such systems may reduce dependence on wild-caught fry, which often have uncertain genetic backgrounds and inconsistent production performance. Fingerling growth performance observed in the present study was comparable with previous studies conducted under semi-intensive Nile tilapia production systems (Yimer and Tigabu, 2016; Oumer et al., 2016; Mohammed and Tessem, 2017). The growth response may be attributed to the adequate dietary protein level, appropriate feeding management, and suitable pond environmental conditions maintained throughout the culture period.

Male broodstocks showed significantly higher growth performance than females, which agrees with previous observations in Nile tilapia. This difference is likely related to sex-specific energy allocation, where females invest considerable metabolic energy into egg production and mouth brooding, whereas males can allocate greater portion of available energy toward somatic growth (Engdaw and Geremew, 2024). Furthermore, endocrine regulation, feeding behavior, nutrient utilization efficiency, and reproductive physiology contribute to the enhanced growth efficiency observed in male broodstocks (Wonand Borski, 2013).

The success of production of fingerlings using locally available feed resources provides an important opportunity to demonstrate a considerable potential of low-cost, on-farm hatchery technologies to strengthen aquaculture development in Ethiopia. Limited hatchery capacity, inadequate access to quality broodstocks, and high feed costs remain major barriers to expansion of small-scale fish farming. The production approach evaluated in this study offers a practical alternative for improving seed availability through affordable pond-based hatchery systems (Yimer and Tadesse, 2022) reported that the efficient utilization of locally available feed resources and improved feed formulation are among the most effective approaches for enhancing Nile tilapia growth performance and reducing production costs in Ethiopian aquaculture. Nevertheless, further research is required to evaluate long-term broodstocks reproductive performance, improve feed formulations using locally available ingredients, assess genetic quality of produced seed, and validate the economic performance of this technology under different farming conditions. Such studies will support wider application of sustainable small-scale Nile tilapia seed production systems.

This study demonstrated the feasibility of small-scale Nile tilapia (*Oreochromis niloticus)* seed production using earthen ponds and locally formulated feeds under Ethiopian farming conditions. The application of an on-farm formulated diet significantly improved fish growth performance compared with extensive production conditions, indicating the importance of appropriate feed management in improving productivity within smallholder aquaculture systems (Onomu and Okuthe, 2024; Irabor et al., 2026). The locally prepared diet based on fish meal, soybean meal, and wheat bran provided adequate nutritional support for broodstocks growth, reproduction, and fingerling development. The successful production of fry and the growth performance of both broodstocks and fingerlings indicate that affordable, locally available feed resources can support decentralized seed production without complete dependence on commercial feeds. The study further demonstrated that a small earthen pond system can contribute to improving the availability of quality Nile tilapia seed which is in agreement with El-Sayed et al. (2023), Echessa, (2024) and Wasso et al. (2024). The production of approximately 3,300 fry per spawning cycle from managed broodstocks suggests considerable potential for increasing fingerling supply at the farmer level and reducing dependence on wild-collected seed, which often has uncertain quality and productivity. Male broodstocks showed superior growth performance compared with females, while fingerlings achieved estimated growth under the formulated feeding regime which is in consistence with (Furuya et al., 2023; Engdaw and Geremew, 2024; Sayouhet al., 2024) These findings confirm that appropriate broodstocks management combined with locally formulated feeds can enhance biological performance and production efficiency in small-scale hatchery systems. Overall, the integration of improved broodstocks management, locally available feed ingredients, and farmer-oriented fry production technologies provides a practical pathway for sustainable Nile tilapia aquaculture development in Ethiopia. Promotion of such low-cost seed production approaches through extension services and farmer training platforms could improve access to quality fingerlings, strengthen rural aquaculture enterprises, and contribute to food security and livelihood improvement. Further studies should evaluate long-term brood stocks reproductive performance, genetic quality of produced seed, and economic performance under different farming environments.

DECLARATIONS

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Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Author's contribution

Y. Aynalem: Conceptualization, methodology design, experimentation, data collection and analysis, manuscript drafting and editing.

A. Yalew: Assist with the concept and design of the experimental setup, follow-up, and supervision, providing critical comments on the manuscript, reviewing the manuscript, and editing

G. Tilahun: Conceptualization, supervision, visualization, original draft preparation, critical review, and editing

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Ethical approval

This study strictly address to established ethical guidelines for animal welfare, ensuring the humane handling of Nile tilapia throughout the research. All experimental procedures were carried out with utmost care to minimize stress on the fish. Data collection, analysis, and reporting were conducted with full transparency, and complete datasets are available to ensure verification and reproducibility. The experimental protocol was reviewed and approved by the Institutional Review Board (IRB) of Bahir Dar University, Bahir Dar, Ethiopia, under protocol number 02/IRB/22.

Competing interests

The authors declare no competing interest in this research and publication

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