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Establishment and efficiency evaluation of a simple mini hatchery for production of *Oreochromis niloticus* (GIFT strain) seeds

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Abstract. A simple technology mini hatchery was established for small scale farmers to meet their own GIFT seed requirements. Different shapes and sizes of jars were trialed for incubation of eggs and yolk-sac larvae. Concaved bottom round plastic bottles (4 L) and rectangular (3 L) plastic trays gave the best hatchability of eggs and survival of yolk-sac larvae respectively. The best stocking density was 500 eggs/larvae L^{-1}. Optimised flow rate into the incubation bottles and rearing trays were 2.70±0.18 L min^{-1} and 5.40±0.14 L min^{-1} respectively. Two gravel filters (15 L and 20 L) made with discarded and low cost material purified the water from the incubation containers and directed into a water recirculation system. Production efficiency of this mini hatchery was compared with a hapa breeding method. Two hapas having 10 m^3 size and 1.6 mm mesh were positioned in an earthen pond. Each hapa was stocked with 40 GIFT broodfish at 1:1 female to male ratio. In Phase I of the study (60 days), eggs collected from Hapa I were placed in incubation bottles and hatchability and survival rate were determined. In parallel, free-swimming fry were collected and counted from the Hapa II at every 14 days. The study continued in the same way for Phase II (next 60 days) by interchanging the brood fish between Hapa I and Hapa II. Yield from the mini hatchery (24,000 fry) was significantly different ($P \leq 0.05$) from hapa method (4,879 fry) indicating that this established mini hatchery could serve as a productive model to support small scale farmers in GIFT seed production.

Keywords. Incubation; mini-hatchery; Tilapia; hatchability; survival rate

1 Introduction

Genetically Improved Farmed Tilapia (GIFT), a developed commercial strain of *Oreochromis niloticus* (L) was introduced first time to Sri Lankan inland waters in 2001 (Wijenayake *et al.* 2007). They feed on wider range of natural as well as artificial feeds, grow rapidly, have delayed early maturity and able to tolerate poor water quality conditions over other strains in the same species. These are the favored characteristics of GIFT to establish over wider range of culture environments (Eknath *et al.* 1993; Macranas *et al.* 1993; Bentsen *et al.* 1998; Nguyen *et al.* 2011).

GIFT fish has become most preferred tilapia strain in all types of aquaculture systems in Asia (Dey *et al.* 2000). Culture based fisheries rely on stocking of fish fingerling in small seasonal reservoirs whilst capture fisheries are carried out in large perennial reservoirs. In 2013, 82% of total inland fish production came from capture fisheries in Sri Lanka. Both culture based fisheries and capture based fisheries rely on stocking seeds periodically. Government hatcheries currently maintain broodstocks of GIFT in earthen ponds and supply seed (fry and fingerlings) for the stocking programmes (NAQDA, 2014). However, no evidence is found whether there are attempts to maintain genetic quality of GIFT strain in the government hatcheries.

Seed production remains a significant bottleneck to the continued expansion of tilapia aquaculture and fisheries due to supply cannot meet the demand. Tilapia seeds can be produced in hapas, concrete tanks, and fiberglass tanks while earthen ponds are widely used (Green, 2006). If fertilized eggs or sac-larvae collected from mouth incubating females are given artificial incubation, daily production may become higher and total output can be greater (Green, 2006). Countries like the Philippines, Thailand, Indonesia, India and Bangladesh are well adapted for artificial incubation systems in large scale tilapia fry production, and produce millions of fry-fingerling to fulfill seed requirement of those countries (Green, 2006).

In Sri Lanka, there is no such large scale or small scale artificial hatchery systems operated for tilapia. Farmers have to bear high transport costs in addition to the purchasing cost of seeds from the government hatcheries. As such, establishment of backyard hatcheries for tilapia fry production is a meaningful strategy for further expansion of tilapia aquaculture. Accordingly objectives of the study were to establish a simple mini hatchery (artificial incubation system) which could be operated by fish farmers, and to compare the hatchability, survival and total production of seeds in the mini hatchery with those in a breeding hapa installed in an earthen pond.

2 Material and Methods

The study site was a home backyard of a fish farmer near to Kattakaduwa perennial reservoir in Hambantota District. A hut made of bricks (4.5 m x 7.5 m), two earthen ponds each of 500 m^2, two cement nursery tanks each of 6 m x 3.6 m, owned by the farmer were used. Water for the hatchery was supplied from water well. GIFT fingerlings (average weight 1.44±0.14 g) were obtained from Aquaculture Development Centre at Iginiyagala of National Aquaculture Development Authority of Sri Lanka. Fingerlings were reared in an earthen pond at the study site until they became sexually mature, and fed with a commercial diet with 25% crude protein level. Figure 1 and Plate 1 show the area of the established mini hatchery..

Figure 1. Kattakaduwa at Hambantota district

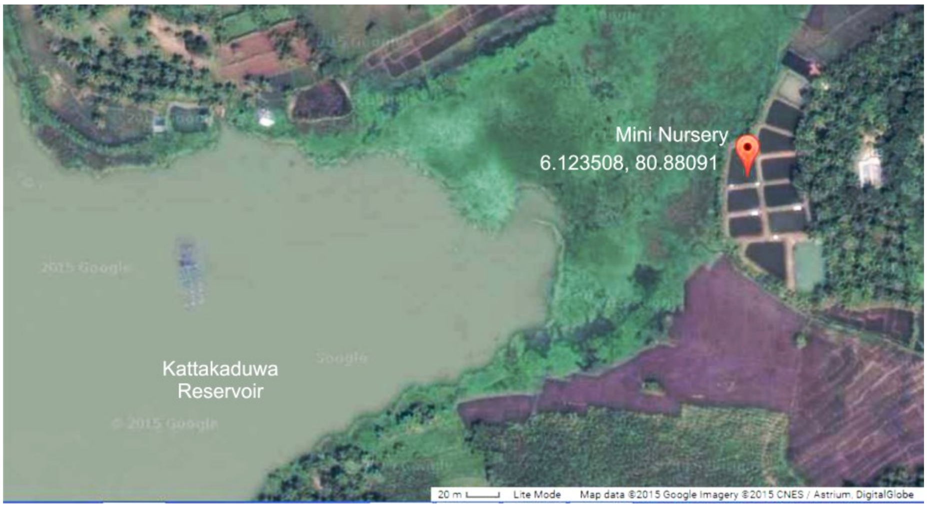

Plate 1. An aerial image of the mini hatchery established at Kattakaduwa

Recirculation water supply system was developed for the hatchery. This includes an overhead tank where the well water is pumped in, a ground tank to stock water coming from the hatchery unit, and two simple gravel filters (large and small) having volumes of 25 L and 15 L respectively. Outflow water from the mini hatchery was directed through gutters into gravel filters and stocked in the ground tank. This filtered water was pumped into the overhead tank. Water recirculation was automated using a floating valve fixed in the overhead tank. Twelve transparent round plastic bottles (4 L) with concave bottoms were used to incubate the eggs. Plastic trays (3 L) having dimensions of 40 cm (L) x 28 cm (W) x 4 cm (H) were used for yolk-sac larvae rearing. Water into the hatchery jars and larval rearing containers was supplied by down-welling pipes (1.25 cm diameter) which are commonly used by the hatchery operators (Bhujel, 2008). Inflow water was supplied to the bottom of each bottle and side (28 cm, width) of the trays through a 1.25 cm diameter PVC pipe. Outflow water removed from the top of the bottle via a 2.5 cm pipe and through a series of holes pierced and covered with 1.5 mm nylon net at the 40 cm sides of the trays. The line diagram of the water recirculating system of the hatchery system is appeared in Figure 2. Through pilot trials, flow rate of water to hatchery jars and rearing trays were adjusted to get an optimal hatchability of eggs and survival rate of yolk-sac larvae respectively.

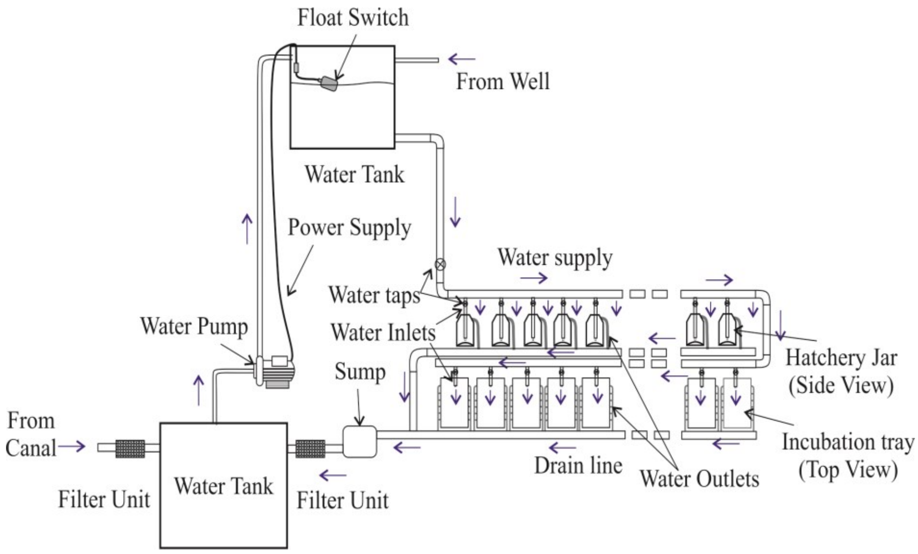

Figure 2. Line diagram of the mini hatchery unit

Two hapas (namely I & II), each with 10 m^3 water capacity were established in an earthen pond. Hapa I was made of 1.6 mm mesh size single layer nylon net (Figure 3). Hapa II consisted of double-net system which contained a smaller hapa with 5 mm mesh size suspended inside the larger hapa having 1.6 mm mesh. Brood fish were confined to inner hapa whereas free-swimming fry were allowed to pass to the outer hapa (Figure 3).

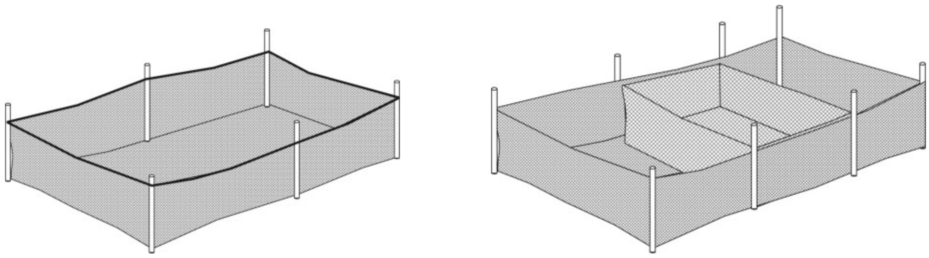

Figure 3. Happa I and II established in the earthen pond

Twenty male fish and 20 mature female in 1:1 ratio GIFT fish, with average weight of 150 ± 12.3 g and 125 ± 17.5 g, respectively, were stocked in each hapa. The study was carried out in two phases. In Phase I, eggs were collected in 7- day intervals from the mouth-brooding females of broodstock A (hapa I), and stocked in incubation bottles at a stocking density of 500 eggs per liter. Yolk-sac larvae emerged, were collected from incubation bottles, placed in larval rearing trays at a stocking density of 500 per liter. Hatchability of eggs and survival rates of fry were determined.

In parallel, eggs collected from broodstock B (hapa II) were used for hapa breeding method. Free-swimming fry in the hapa were collected at every two weeks. The study was continued for two months, and after two months, broodstocks in hapa I and II were interchanged and the study was continued in the same manner over further two months. Interchange of brood stock was done to compensate for the errors due to any variation of brood fish used in the study.

The following reproductive parameters; hatchability of eggs, survival rate of yolk-sac larvae and fry production per female were determined according to Tahoun *et al*. (2008). At the end of the 120 day study, total fry produced from both breeding methods were compared. The following water quality parameters; dissolved oxygen, pH, water temperature and conductivity were monitored using a portable multifunction instrument/ meter (Eutech Instrument, USA).

Hatchery phase and hapa phase experiments were replicated eight and four times respectively, and the means of each replicate were used to compare the productive and reproductive performance of broodstock in different phases. Data were analyzed by one way analysis of variance to determine the effect of two seed production methods on GIFT seed production using SPSS Version 16 statistical package.

3 Results

Several trails had to be carried out to optimize the best flow rate and stocking densities for the incubation bottles (hatchery jars) and larval rearing trays for consistent hatching and survival rates of GIFT eggs and fry respectively. Optimised flow rates were 2.70 ± 0.18 L.min^{-1} for egg incubation and 5.40 $\pm$0.14 L. min^{-1} for yolk-sac larvae rearing. Flow rates resulted in an average of 90 % survival for yolk-sac larvae and over 90 % hatchability for eggs. Number of eggs and yolk-sac larvae that gave the best survival at these flow rates was 500 individuals L^{-1} (Senaarachchi & De Silva, 2014).

Increased flow rate in both containers resulted in lower egg hatching rates and survival rates of yolk-sac larvae due to mechanical damages created by high flow rates. Similarly, lower flow rates (< 2 $L.min^{-1}$) resulted in clogging of eggs at the bottom affecting the hatchability. Also, in larval rearing plastic trays yolk-sac larvae clogged followed by fungal attacks. Hatchability and survival rate of yolk-sac larvae in artificial plastic incubators under optimised flow rates were over 80 % and 90 % respectively (Senaarachchi & De Silva, 2014). Mini hatchery consisting of 12 bottles (egg incubation jars) had 48,000 eggs loading capacity and 10 rearing trays had yolk-sac larvae loading capacity of 40,000 larvae per month.

Table 1. Productive performance (mean± SD) of GIFT

Parameters (mean± SD)*	Phase I (First 60 days)	Phase II (Second 60 days)
Artificial Hatchery	Brood stock A	Brood stock B
Mean weight of female (n=20)	125 ± 17.5^a g	186 ± 12.5^b g
Productive performance		
Percentage hatchability of eggs	93.69 ± 2.79^a	94.58 ± 4.21^a
Percentage survival rate of sac larvae	95.20 ± 3.02^a	95.49 ± 2.05^a
Total fry production/ 20 females in 60 days	10294^a	13706^b
Fry / female / 60 days	514.7^a	685.3^b
Fry / female/ day	8.56^a	11.42^b
Fry / m^2 / day	17.14^a	22.88^b
Hapa Breeding	Brood stock B	Brood stock A
Mean weight of female (n=20)	125 ± 17.5^a g	186 ± 12.5^b g
Productive performance		
Total fry production/ 20 females in 60 days	2394^a	2485^a
Fry / female/ day	1.98^a	2.06^a
Fry / m^2 / day	3.98^a	4.14^a

*Means in the same raw having different letters are significantly different ($P \leq 0.05$)

According to Table 1, there is no significant difference ($p>0.05$) in hatchability of eggs and survival rate of yolk-sac larvae between two brood fish groups (A and B). Weight of the specimens of brood stock increased from 125 ± 17.5 g to 186 ± 12.5 g during first phase of the study (60 days). Weight increase of the female brood fish however had significantly ($p \leq 0.05$) influenced the total fry production in the broodstock B used in the Phase II hatchery system (Table 1).

In hapa breeding method, seeds produced by brood stock B and broodstock A had no significant difference in overall seed production during two phases (Table 1). When compared to the artificial incubating system, total productivity was significantly low in hapa breeding method (Table 2). Mini hatchery produced 24,000 fry over 120 days from 40 GIFT broodfish which is significantly different to hapa method that produced 4879 fry per 120 days with the same number of brood fish (Table 2). Water quality parameters were not significantly different (p>0.05) between mini hatchery and pond water during the study period (Table 3).

Table 2. Effectiveness of two seed production methods

Productive parameters (mean± SD)*	Hatchery	Hapa breeding
Total fry produced/ 40 females in 120 days	24000^{a}	4879^{b}
Mean fry production	600 ± 85.3^{a}	121.97 ± 2.27^{b}
Fry/ day	9.99 ± 1.43^{a}	2.02 ± 0.04^{b}
Fry/ m^2 / day	20.01 ± 2.87^{a}	4.06 ± 0.08^{b}

*Means in the same raw having different letters are significantly different (P ≤ 0.05).

Table 3. Comparison of water quality parameters

Water quality parameter (mean± SD)*	In the hatchery	In the pond
Temperature (^{0}C)	29.71 ± 0.73^{a}	30.10 ± 0.74^{a}
Dissolved oxygen (ppm)	5.82 ± 0.60^{a}	5.68 ± 1.51^{a}
pH	7.66 ± 0.6^{a}	7.45 ± 0.51^{a}
Conductivity	-85.54 ± 19.99^{a}	-79.85 ± 16.88^{a}

*Means in the same raw having different letters are significantly different (P ≤ 0.05).

4 Discussion

Seed requirement is one of the major factors which directly affect on sustainability and productivity of any aquaculture system. Many countries have developed mechanisms to face the problem by establishing hatcheries in small scale and large scale to address this issue. One of the major constraints is the scarcity of seeds in large numbers when required. A mini hatchery (artificial incubation system) with simple technology, which could be operated even by an unskilled fish farmer to get his/her own seed supply was established in the present study. Productivity was evaluated comparing with generally accepted hapa seed production method. Stocking density of brood fish was maintained at 4 fish m^{-2} and it was accordance with that of Ridha & Cruz (1999). According to them, seed production of *O. niloticus* in a recirculation tank hatchery system was significantly reduced with increased number of brood fish above 4 fish m^2.

Significant reduction of spawning success was recorded in *O. niloticus* at increased brood fish stocking density (Ridha & Cruz, 1999; Little, 1989; Ernst *et al.* 1991; Bhujel, 2000). According to Rana (1986) and Macintosh and Little (1995), down-welling round bottom incubators having the capacity 2 - 3 L resulted in 17 to 22 % hatchability and survival rate of the yolk-sac larvae was 85 %. In contrast, the present study gave hatchability of eggs over 90 %.

This might be due to the churning of eggs in the bottle with concave bottom. The flow rate of water to the rearing trays stocked with yolk-sac larvae was 5.4 $L.min^{-1}$. Over 90 % survival rate was observed in plastic trays for 3 days old yolk-sac fry upto 10 days old free-swimming fry. Tilapia eggs are negatively buoyant and in the absence of a water current, eggs tend to sink quickly and clump. Eggs loading rate ranged from 650 to 1350 eggs per liter in small incubators (2 - 3 L soft drink bottles) and the water flow rates are 1 L. min^{-1}. In large incubators (20 L) flow rate 1 L. s^{-1} per 10,000 eggs (Little, 1989; Macintosh & Little, 1995). In the present study, the stocking density of eggs in incubation bottles was more or less similar to those findings of previous studies but the flow rate was (2.7 L. min^{-1}) for 4 L bottle. This comparison highlights that the flow rate should be adjusted according to the size and shape of the incubator.

Phase II experiments with A and B brood stocks started just after 60 days (Table 1). Total number of fry produced in the Phase II was higher than that in the Phase I both in mini hatchery and hapa systems.

Production of mixed sex/age fingerling is often done in earthen ponds, at a stocking density of 0.3 to 1 brood fish per square meter (Broussard *et al.* 1983; Mires, 1983; Little, 1989; Green *et al.* 1994 ; Hulata, 1997). Partial harvests of reproduction ponds are conducted at weekly intervals and the daily seed productivity is 1.5 to 4.5 seeds m^{-2} with a stocking ratio of 4:1 female and male brood fish (Broussard et al., 1983; Little, 1989; Green et al., 1994; Hulata, 1997). In the present study too, fry production resulted more or less similar seed productivity at the same brood fish stocking density of hapa (Table 2). Reduction of seed production in natural breeding is mainly due to the 6 to 7 days old fry are more susceptible for cannibalism when commencing exogenous feeding (Macintosh and De Silva, 1984).

Stocking three, four, five, seven, or ten Nile tilapia female brood fish per male in hapas also had yielded similar daily seed production indicating that sex ratio does not have much affect on the daily seed production (Broussard *et al.* 1983; Guerrero & Garcia, 1983).

The reproductive performance of tilapia is expected to decline with age according to Ridha and Cruz (1989) who reported that year class I Nile tilapia brood stock had a higher female fecundity than year class II. However, in the present study such effect may not have taken place as the broodstocks were approximately 9 months old and the duration of the present study was short (120 days).

Large amount of water is needed for the better function of the hatchery. Water recirculation system maintained the required water volume even in drought season when the well water was not amply available. Also the low cost simple gravel filters maintained the water quality at optimum levels. In a hatchery maintaining broodstock genetic diversity is very important to get viable, strong and disease free seeds. In this mini hatchery quality of genetic diversity is not determined. Changing the broodstock in between 1-2 years as well as selective breeding could enhance the quality of seeds.

Removal of eggs/ yolk sac-fry at 7 days intervals and grown in an artificial incubation system significantly increased the seed production compared with natural egg incubation in hapa established in a pond. Since total fry production and fry production per m^2 were greater in artificial incubation system, the mini hatchery established provided a simple productive facility for seed production for small scale farmers. There is a possibility for the backyard mini hatchery concept to the Indian and Chinese carp breeding.

Conclusion

Mini hatchery established for GIFT fish is a productive and simplified incubation system. Since no advanced techniques are involved, inexpensive material, ability to operate by a single fish farmer in a small area, this mini hatchery could be used as an effective facility to produce tilapia fry to fulfill seed requirements of small scale fish farming systems.

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