TOPIC AREA

QUALITY SEEDSTOCK DEVELOPMENT

BROODSTOCK SEED QUALITY AND FINGERLING PRODUCTION SYSTEMS REARING FOR NILE TILAPIA IN THE PHILIPPINES

Quality Seedstock Development/ Experiment/ 07QSD01NC

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ABSTRACT

Tilapia seed production in the Philippines is estimated at over 1.2 billion annually with demand expected to triple. To improve food security efforts are require to increase hatchery development and enhanced technologies for consistent and quality seed production. In a series of studies we evaluated seed production and growout performance of Nile tilapia (*Oreochromis niloticus*) as a function of broodfish age (8, 12, and 24-month old) as well as the effectiveness of different hatchery systems, namely artificial incubation units, hapas (fine mesh net pens), and ponds on survival, growth, sex conversion rate and size distribution of fry and on fingerling growout. We utilized the GIFT strain of Nile tilapia, a genetically enhanced cultivar commonly used throughout the Philippines and Southeast Asia. In the first study, we found that 8- and 12-month old broodstock had higher spawning rates, albeit statistically insignificant relative to 24-month old broodstock. Despite the older broodstock having produced the highest percentage of hatched eggs ($P < 0.05$), the youngest broodfish tended to have higher levels of total seed production as measured by the combined number of hatched-eggs, swim-up fry and fry produced ($P > 0.05$). In a second study we investigated pond growout of fingerlings produced from broodstock of different ages. We found that fingerling survival, final body weight, specific growth rate, and extraplated gross yield did not differ with broodstock age. It is concluded that broodstock ranging in age from 8 months to 2 years can be used for GIFT tilapia seed production with little impact on gross yield of marketable fish. In a third experiment, we found no significant difference on growth in hapas among fry hatched in artificial

incubation units, hapas, ponds or the combination of the three systems. However, fingerlings produced from fry hatched in artificial incubation units were found to be of two sizes only (mean wt. = 0.2-0.25 g: mean wt. = 0.3-0.35 g) while those raised from fry hatched in hapas, ponds and combination of the three systems were more variable in size. Survival rates were highest in fry-hatched from artificial incubation group and differed significantly from those derived from hapas or a combination of systems. Overall, it appears that artificial incubation unit-hatched fry had significant advantages on percent survival and size uniformity after the sex reversal treatment in hapas under the temperature range of the study (26.9 – 29.1°C). This may reflect less handling, lower stress and reduced cannibalism, factors to consider in tilapia hatchery operations. We then evaluated if the 120-day growout performance of size-matched fingerlings derived from fry reared in the different hatching systems. We found no significant differences among treatments in any of the performance variables, including survival, final weight and length, specific growth rate, feed conversion, and yield. We conclude that any of the three most common tilapia hatchery systems can be used to supply fingerlings for the growout production of Nile tilapia.

INTRODUCTION

Nile tilapia (*Oreochromis niloticus*) seed production in the Philippines is estimated at over 1.2 billion annually with demand expected to triple (Bureau of Fisheries and Aquatic Resources, BFAR 2005; ADB 2005). There is a strong push and government effort to improve food security through increased hatchery development and enhanced technologies for consistent and quality seed production. The goal is to provide year-round, high-quality seed that can be widely distributed at reasonable costs to both increase income and reduce perceived risks to tilapia farmers. Fry and fingerlings either produced on farm or purchased represent a considerable investment to farmers, constituting around 15% of total cash costs for crop production, second only to feed (ADB 2005). Here, we aim to assess seed production efficiency as a function of broodstock age and different rearing production systems to evaluate better the hatchery and nursery practices intended to increase seed yield without a negative impact on fish growout performance.

It is well established that broodstock age and size, among various other factors, can affect seed quality and fecundity in farmed fish (Bromage, 1995; Green *et al*., 1997; Siddiqui and Al-Harbi, 1997). Previous studies show that small Nile tilapia broodstock produce more eggs than larger fish while larger broodstock produce more eggs per clutch than smaller ones. Work in other species, *T. zillii*, *T. tholloni*, and *S. melanotheron,* shows no direct correlation between fish size and fecundity (see El-Sayed, 2006). With regard to age, seed production per female was higher for 3-year-old compared with 1-year-old hybrid tilapia bred in concrete tanks. However, seed production as a function of broodstock biomass or density was best in 1-year-olds compared with 2-, 3-, and 4-year olds (Siddiqui and Al-Harbi, 1997). In red tilapia and *O. spilurus* 1-year old broodstock produce a greater number of seed than older age class fish (Ridha and Cruz, 1989; Smith et al. 1991). To our knowledge an evaluation of broodstock age on gamete quality (survival and growth) has never been done for the genetically improved GIFT (Genetically Improved Farmed Tilapia) strains of Nile tilapia. The GIFT strain is selectively bred for rapid growth and presently distributed by the GIFT Foundation International, Inc. It is widely used throughout the Philippines and Southeast Asia and its rapid expansion as a choice of tilapia farmers is supported by estimates that it can produce cost savings as much as 25% (Dey 2000). The GIFT Foundation is an independent organization that works with and refines genetically improved strains of Nile tilapia for food production (see Dunham et al., 2000).

These fish enjoy widespread popularity because of their enhanced growth and feed utilization parameters, but additional refinements in hatchery technology would be beneficial; for this reason our studies will evaluate the effects of age of broodstock on the viability of progeny.

Additional studies assessed the efficacy of three artificial and natural seed rearing systems (artificial incubation units, hapas and ponds) on fingerling production characteristics (survival,sex inversion, and yield) and the subsequent growout performance of tilapia. These systems encompass the growout methods being used on either family farms or small/medium-scale hatcheries in the Philippines, and there is considerable interest by farmers and state and private hatcheries on the relative impact each might have on fingerling production and subsequent growout.

OBJECTIVES

± Examine the effect of broodstock age on seed production and fingerling growout performance of genetically improved tilapia strains

± Assess the size distribution, growth and survival of fry and fingerling growout performance of tilapia seed produced from artificial incubation units, hapas, and ponds

MATERIALS AND METHODS

Study 1 - *Effect of age of broodfish on the seed production of GIFT strain of Nile tilapia*
There were three (3) treatments reflecting different broodstock ages that were replicated four times using a random block design. Treatments were as follows: Treatment I – 8 month-old broodfish, Treatment II – 1 year-old broodfish and Treatment III – 2 year-old broodfish.

Different aged broodfish of the GIFT strain (GIFT Foundation International Incorporated, GFII) were conditioned in 2.5 m x 10 m x 1 m fine mesh hapas installed in 2,500 m^2 ponds for one week prior to stocking in breeding hapas. Male and female broodfish were initially separated during the conditioning period and fed at 09:00 h and 14:00 h at 3% body weight per day on acommercial feed (30% crude protein). Animals were then weighted and 13 males and 39 females (1:3 male:female) were stocked into each breeding hapa (2.5 m x 10 m x 1 m). Water quality parameters including dissolved oxygen (mg L^{-1}) and water temperature (°C) were monitored daily at 09:00 and 15:00 h. After 14 days, eggs from mouthbrooding females as well as swim-up fry and fry were collected from each hapa. Collected eggs were pooled and were incubated in incubation jars until the swim-up fry stage. The swim-up fry were counted and included in the fry counts. The combined number of hatched eggs, swim-up fry and fry served as the index of seed production for each treatment or broodfish age.

At the end of the breeding period, the number of broodfish that spawned was recorded to determine spawning success. Spawning success of female broodfish was determined based on morphological characteristics, whereby broodfish with red genital papilla shrunken to a compressed abdomen were categorized as “had spawned”, and broodfish with a white to clear flat genital papilla and normal abdomen were categorized as “not ready to spawn” (WorldFish Center, 2004).

Differences in average seed production with broodfish age was analyzed by ANOVA followed by the Least Significant Difference test for predetermined comparisons of means (Version 11, SPSS Inc., Chicago IL).

Study 2 - *Effect of age of broodfish on the grow-out performance of Nile tilapia fingerlings*
This study was composed of four treatments and replicated three times using a random block design. Treatments were as follows: I – sex-reversed Nile tilapia produced from 8-month old broodfish, II - sex-reversed Nile tilapia produced from 1- year old broodfish, III - sex-reversed Nile tilapia produced from 2-year old broodfish and IV – combination of sex-reversed Nile tilapia produced from different ages of broodfish.

Sex-reversed Nile tilapia fingerlings (0.192 – 0.208 gram) produced as described above from GIFT-strain broodfish of different ages were used. Fingerlings were stocked in twelve (12) 500 m^2 earthen ponds at 4 fish m^{-2} or 2000 $pond^{-1}$. Stocked fingerlings were fed twice a day^{-1} with commercial feeds at a daily rate of 20% down to 3% body weight. Fifty fish were sampled monthly for average weight and length. At the end of the 120-day culture period, 200 fish or 10% of the total fish stock were sampled for individual weight and length.

Ponds were fertilized with ammonium phosphate (16-20-0) and urea (46-0-0) at 28 kg N and 5.6 kg P ha^{-1} $week^{-1}$ to enhance the growth of natural foods in pond water. Secchi disc visibility was maintained≤40cm. atWater quality parameters including dissolved oxygen and water

temperature were monitored weekly in the morning beginning at 09:00 h. Air temperature (°C), rainfall (mm) and photoperiod data were gathered at the local PAGASA station located at Central Luzon State University, Science City of Muñoz, Nueva Ecija.

Differences among treatment means were analyzed by ANOVA followed by Duncan's Multiple Range Test.

Study 3 - *Size distribution, sex conversion rate, growth and survival of Nile tilapia fry produced in artificial incubation units, hapas and ponds*
Four treatments were tested in triplicate using a random block design. Treatments are as follows; I – artificial incubation unit-hatched fry, II – hapa-hatched fry, III – pond-hatched fry and IV – combination of hatched fry (artificial incubation units, hapas and ponds). Tilapia breeders of the same cohort (GIFT selected generation 11; 1.5 years old) were used to produce fingerlings in artificial incubation units, hapas and ponds at the GFII facility. Prior to breeding, female and male broodstock were separated and conditioned for 7 days in hapas (2.5m x 10m x 1m) installed in a 5,000-m^2 pond. Breeders were fed at 3% body weight per day during the morning and afternoon. Prior to stocking for breeding, broodfish weights and lengths were ascertained to attain similar average broodstock sizes in the production systems.

For fry production in artificial incubation units, seven fine mesh hapas (2.5m x 10m x 1m) installed in a 5,000 m^2 pond were stocked with 48 broodfish each at a 1:3 male:female ratio. On the 10th day fertilized eggs were collected from the mouth of female breeders and incubated in round bottom jars (aritificial incubation units) for nine days until swim-up fry stage. For fry production in hapas, 7 separate hapas were stocked with breeders five days after the initial stocking of the first 7 hapas used for egg collection. Hapas were stocked with 48 breeders each at a 1:3 male:female ratio. Then 14 days later, breeders were removed and then swim-up fry were collected by scoop net. For fry production in ponds, four 100 m^2 ponds were each stocked with 200 breeders at a 1:3 male:female ratio 6 days following initial stocking of breeders used or egg collection and fry production in artificial incubation units. After 15 days of breeding, ponds were partially drained, and tilapia fry were collected by scoop net. This schedule of breeding ensured synchronized spawning of breeders and the production of fry with uniform size and age from the 3 different hatching or fry production systems.

Following collection of fry from incubation units, hapas and ponds, animals representative of each system were pooled and initially conditioned for six hours in 1m x 2m fine mesh hapas (15,000 fry $hapa^{-1}$) prior to stocking in nursery hapas. Swim-up fry from the different sources were graded to ensure uniformity in size and then stocked and reared in twelve 2m x 4m x 1m fine mesh nursery hapas for 23 days at a density of 850 fry $m\text{-}^2$ or at 6,800 fry $hapa^{-1}$. Stocking of fry from each production system was done rapidly and at the same time to minimize variation in stocking time and to prevent mortality resulting from handling and thermal stress. Fry representative of each production system were stocked in triplicate nursery hapas.

Fry were sex reversedα to produce male populations using feed impregnated with 17 -methyltestosteroneα. 17 -methyltestosterone was applied to fry mash feed at a concentration of 50 mg Kg^{-1} feed using ethanol as vehicle. The feed was mechanically mixed, air- dried and then fed to fry in nursery hapas for 23 days at a rate of 30, 20 and 10% of the fish body weight for the first, second and third week, respectively. Fry were sampled weekly for weight and length. At the end of the 23-day-sex-reversal treatment, growth, survival and size distribution of the fingerlings were determined.

Data gathered in this study included the following: size distribution, mean length and weight before and after sex reversal treatment in hapa, specific growth rate, percent survival, and some water quality parameters. Differences among the fry rearing systems were analyzed using ANOVA followed by the Least Significant Difference for predetermined comparison of means using Statistical Analysis Software (SAS) Version 9.0.

Study 4 – *Fingerling growout performance of Nile tilapia produced in artificial incubation units, hapas and ponds*

This study was composed of four treatments and was replicated three times. Treatments were as follows: I - sex-reversed Nile tilapia fingerlings derived from fry produced in artificial incubation units, II - sex-reversed Nile tilapia fingerlings derived from fry produced in hapas, III - sex-reversed Nile tilapia fingerlings derived from fry produced in ponds and IV - sex-reversed Nile tilapia fingerlings derived from fry produced in mixed sources of hatching systems (artificial incubation units, hapas and ponds).

Sex-reversed Nile tilapia fingerlings of the GIFT strain (weight range = 0.260 – 0.340 g) derived from fry produced from different hatching systems (artificial incubation units, hapas and ponds; See *Study 3*) were used in the study. Fingerlings were stocked in twelve 500 m^2 earthen ponds at 4 fish m^{-2} or 2000 fish $pond^{-1}$. The fingerlings were fed twice a day with commercial feeds at 20% of the body weight from 0-2 weeks, 10% of the body weight from 2-4 weeks, 7% of the body weight from 4-6 weeks, 6% from 6-8 weeks, 5% from 8-10 weeks, 4% from 10-12 weeks, 3% from 12-16 weeks.

Ponds were fertilized with ammonium phosphate and urea following the recommended fertilization rates of 28 kg N and 5.6 kg P ha^{-1} $week^{-1}$ to enhance the growth of natural foods. Water quality parameters including dissolved oxygen and water temperature were monitored weekly.

Five percent or 100 fish per replicate per treatment were sampled monthly by cast net method for determination of average weight and length. Fish from each treatment and replicate were manually sexed at the end of the 120-day culture period to determine the total number of males and females. At the same time, all fish were weighed individually to determine gross fish production (yield), size distribution, survival and feed conversion ratio (FCR).

Differences among treatment means were analyzed by ANOVA followed by the Least Significant Difference test for predetermined comparisons.

RESULTS AND DISCUSSION

Study 1 - *Effect of age of broodfish on the seed production of GIFT strain of Nile tilapia*
Breeders of different ages were stocked at the same sex ratio and density. The weight of male and female broodfish of different age classes were significantly different, with weight increasing as a function of the age of broodstock. The spawning rate did not differ significantly with broodfish age (Table 1).

The number of eggs produced by the different age-class broodstock did not differ significantly, although the the youngest (8-month old) broodstock produced the highest mean number of eggs. The hatching rate increased signficantly with broodstock age (Table 2) with the 2-year age class broodstock producing eggs with the highest hatch rate of 65%. The eggs of older broodstock also appear larger. Collectively, these results cooberate that of Mair et al. (1993) where it was shown that hatch rates of larger *O. niloticus* eggs are greater than smaller eggs, possibly because older females are more experienced egg brooders.

Performance of broodfish on seed production is shown in Table 3 wherein, mean number of hatched eggs, swim-up fry and fry were recorded and analyzed. Eight-month old broodfish produced the highest number of seeds followed by 2-year and 1 year olds. ANOVA revealed no significant difference among treatments at 5% level of significance.

On seed production, no significant difference ($P > 0.05$) was found on the mean number of eggs, swim-up fry and fry, as well as on the spawning rate of the broodfish. The hatching rate in Treatment III was highest and significantly different from Treatments I and II. This shows the hatchability of the eggs produced by older broodstocks were better as compared to the eggs produced by younger broodstocks.

Water quality parameters measured during the breeding experiment fell well within the tolerance range of tilapia and well above levels that may limit production (Boyd 1984). Average dissolved oxygen was 5.48 mg L^{-1} and 7.28 mg L^{-1} in the morning and afternoon, respectively (data not shown). Average water temperature were adequate for reproduction and growth, averaging 24.48 ºC and 28.30ºC in the morning and afternoon, respectively.

Study 2 - *Effect of age of broodfish on the grow-out performance of Nile tilapia fingerlings*
Growth pattern in average body weight and total length among fingerlings derived from broodstock of different ages is shown in Figure 1. Fingerlings produced from 2 year-old broodfish (Treatment III) had the highest final weight and total length (191.458 g; 20.5 cm)

followed by those produced from a combination of broodfish ages (Treatment IV; 182.611 g; 20.2 cm), and then those derived from 8 month-old (162.855 g; 19.5 cm) and 1-year old broodfish (160.401 g; 19.4 cm). However, final weights, and other growth parameters, including specific growth rate, gross yield, feed consumption, and feed conversion were not significantly affected by the age of broodfish (Table 4). Survival rate of stocks following 120-days of culture were also not significantly altered by broodfish age. The highest survival rate of 70% was observed by fingerlings produced from a combination of different aged broodfish, followed by a 61.3% for fingerlings produced from 8 month-old broodfish, and 61% from fingerlings produced from 1 year-old broodfish. The lowest survival rate of 53.8% was in fingerlings produced from 2 year-old broodfish. Highest extrapolated fish yield of Nile tilapia fingerlings produced from different ages of broodfish was obtained in Treatment IV followed by Treatments III, II and I with mean values of 4,472.7, 4,045.3, 3,719.3 and 3,667.3 kg ha^{-1}, respectively. However, no significant differences were observed among treatments ($P > 0.05$).

During the grow-out period, the average minimum air temperature reading was 24.0°C with a maximum of 32.7 °C. Water quality parameters, including water temperature (mean range = 30.3 - 30.4°C) that fell within the optimum range for development and growth of tilapia (Balarin and Haller 1982), dissolved oxygen, and Secchi disc visibility (mean range = 31.9 - 34.6 cm) did not differ among different treatment ponds (data not shown). Dissolved oxygen readings fell within the tolerable range for tilapia, except during week 12 and beyond when DO dropped in all ponds to around 2 mg L^{-1}. Although tilapia have a high tolerance to low DO. A mild incident of mortality of similar magnitude (Treatment I - 4.05%, Treatment II - 5.95%, Treatment III – 10.70%, Treatment IV – 7.25%) was observed among the groups in this study that likely resulted from prolonged exposure to moderately low DO levels (Green and Duke 2006).

Study 3 - *Size distribution, sex conversion rate, growth and survival of Nile tilapia fry produced in artificial incubation units, hapas and ponds*

Fry were produced in either artificial incubation units, hapas, ponds or an equal combination of the three hatching systems and then grown and sex-reversed in nursery hapas for 23 days. The growth pattern of fry produced from the hatching systems was comparable during the first week (Figure 2). From the second week and beyond hapa-hatched fry had higher body weight than artificial incubation unit-hatched fry, pond-hatched fry and combination of hatched fry. Despite hapa-hatched fry having an elevated gain in length and weight and specific growth rate over the 23-day nursery period, there were no significant differences in these parameters among the groups produced from the different hatching systems (Tables 5 and 6; $P > 0.05$).

Survival of fry hatched in incubation units (92.03%) was significantly higher compared with fry hatched from hapas (65.19%) and those hatched from a combination of systems (72.81%)($P < 0.05$; Table 7). Survival of pond-hatched fry (76.50%) did not differ significantly from that of fry produced from incubation units, hapas or a combination of different hatching systems. The lower survival observed in treatments II, III and IV relative to incubation-hatched fry may have resulted from handling stress associated with collection, grading, conditioning and initial stocking of fry for the sex reversal treatment to the nursery hapas.

We also evaluated the size distribution of the fingerlings following growout using commercial graders. Generally, fry derived from the different hatching systems grew to four different size ranges; size 24 (0.06-0.09 g), size 22 (0.10-0.14 g), size 20 (0.16 - 0.20 g), and size 17 (0.25-0.30 g). The majority of fingerlings produced fell within size 24 (Figure 3). Artificial incubation unit-hatched fry had the highest percentage (88.31%) of size 24 as compared to other treatments, and had the lowest percentage of the smaller size grades (size 22, 9.89%; size 20, 1.71%; size 17, 0.09%). Fry hatched from incubation units had the lowest variability (smallest coefficient of variation) of fish in the size 24, 20 and 17 grade relative to the other groups (Figure 3). Collectively, fry hatched in artificial incubation units showed the greatest uniformity in size and presumeably growth rate compared with fry derived from other hatching systems.

Dissolved Oxygen (DO) and water temperature were monitored during the breeding stage. Dissolved oxygen and temperature values during breeding in hapas for collection of eggs for artificial incubation units was 4.46 mg/l (DO range: 2.54-6.1) and 28.39 °C (water temperature range: 27.3-31.9), respectively. Measurements during breeding in hapas and ponds for fry collection were 3.73 mg/l (DO range: 2.61-4.79) and 28.04 °C (water temperature range: 27.2-29.1) and 3.05 mg/l (DO range: 2.72-3.56) and 28.73 °C (water temperature range: 28.03-28.83), respectively (data not shown).

Mean values of dissolved oxygen (DO) and water temperature during sex reversal and fingerling production in hapas were virtually identical among groups with an average DO of 7.39 mg/ml (range within a single group: 6.15-8.5 mg/l) and temperature of 27.76°C (range within a single group: 26.9 – 29.1°C) (data not shown).

Study 4 - *Grow-out Performance of Nile Tilapia Fingerlings From Artificial incubation units, Hapas and Ponds*

Nile tilapia fingerlings that were used in the study had an average body weight of 0.292 g, 0.308 g, 0.320 g and 0.307 g for those derived from fry hatched in artificial incubation units, hapas, ponds, and the combination, respectively. The initial stocking weight of fingerlings from the artificial incubation unit group was significantly lower relative to that of fingerlings derived from the pond-hatched fish ($P < 0.05$; Table 8). There were no other differences among the treatment groups with respect to initial weight at stocking ($P < 0.05$).

Figure 4 shows the average body weight and length of fish from the four treatment groups over the 120-day culture period. At harvest, the highest average body weight of the fingerlings occurred in fingerlings originally hatched in artificial incubation units (179.256 g) followed by those hatched in hapas (168.945 g), a combination of systems (150.042 g) and ponds (138.871 g). The same trend was observed with the daily gain in weight, average length, daily gain in length, and specific growth rate. Overall, there were no statistically significant differences in these variables among treatments ($P > 0.05$; Table 8, Figure 4).

We also evaluated the size distribution of fish at the end of the study. Except for the 251-300 g and 300 g and above size categories, all groups had representative fish in all five of the other size categories (50 g and below, 51-100 g, 101-150 g, 151-200 g, and 201-250 g) (Figure 5). The fish size category most prevalent among the groups was 101-150 g fish, while most fish produced were 101-200 g. Fingerlings derived from artificial incubation units and hapas had a greater number of fish in the three largest size categories. However, with respect to the number of fish produced per size category, analysis of variance showed no significant difference among the groups ($P > 0.05$). Thus each hatching system evaluated is suitable for tilapia grow-out operation.

Survival rates were similar among treatment groups ranging from 56.3% to 59.3% ($P > 0.05$, Table 8). The suboptimal survival rates observed in the study, was likely a consequence of some mortality that occurred in the last month of culture, where fish showed signs of infection likely attributable to streptococcus infection (Alapide-Tendencia and de la Peña 2001). The source of infection is uncertain, but is not likely a result of poor water quality, since DO (mean range, 4.55-4.72), temperature (30.1-30.2ºC), and Secchi disk visibility (33.0-25.7 cm) were within the acceptable range for pond-culture of tilapia.

The FCRs were not significantly different among groups ($P > 0.05$, Table 8). The extrapolated fish yield for fingerlings derived from fry hatched in artificial incubation units was highest (3,890.7 kg ha^{-1}), relative to those derived from hapa (3,797.5 kg ha^{-1}), the combined hatching systems (3,489.0 kg ha^{-1}) and ponds (2,995.1 kg ha^{-1}). However extrapolated yield among groups did not differ significantly ($P > 0.05$; Table 8).

Simple cost and return analyses shows that fingerlings derived from fry hatched in hapas gave the highest net return with PhP 30,732.02 ha^{-1}, followed by those from artificial incubation units with PhP 28,506.50 ha^{-1}, the combined systems with PhP 19,366.88 ha^{-1}, and then ponds with PhP 7,743.16 ha^{-1} (Table 9). Overall, this basic economic analysis indicated that the grow-out rearing of Nile tilapia fingerlings derived from the different hatching systems were profitable. The cost of the different systems for producing fingerlings and labor differences were not included in the analysis, because the intent was only to compare the growout of fingerlings derived from the different hatching systems.

CONCLUSION

The GIFT Nile tilapia is the most commonly used genetically improved strain of tilapia used througout Southeast Asia, including the Philippines. The broodstock age and hatching system that best promote seed production and fingerling growout is uncertain. We assessed seed production efficiency as a function of broodstock age and different rearing production systems to evaluate better the hatchery and nursery practices intended to increase seed yield without a negative impact on fish growout performance. Our studies suggest that older broodfish produce eggs with higher hatching rates, while younger broodstock produce a greater number of seed with lower hatching rates. The growth performance, survival and yield of fingerlings cultured in earthen ponds were also not affected by broodstock age. Based on these studies, we conclude that broodstock ranging in age from 8 months to 2 years can be used for GIFT tilapia seed production with little impact on gross yield of marketable fish.

Additional studies assessed the efficacy of three artificial and natural seed rearing systems (artificial incubation units, hapas and ponds) on fingerling production characteristics (survival, sex inversion, and yield) and the subsequent growout performance of tilapia. These systems encompass the growout methods being used on either family farms or hatcheries in the Philippines, and there is considerable interest by farmers and state and private hatcheries on the relative impact each might have on fingerling production and subsequent growout. Fry hatched from artificial incubation units, hapas, ponds and the combination of the three systems showed no significant differences in specific growth rate, weight gain or length gain. However, the fingerlings produced from artificial incubation unit-hatched fry showed less variability in size after the sex reversal treatment. They also had the highest percent survival (92.03%) among the groups. These results suggest a significant advantage of using artificial incubation unit-hatched fry to produce fingerlings with higher survival and more uniform sizes relative to the other hatching systems. Regardless of the hatching systems from which fingerlings were derived, growth performance, survival and fish yield of fingerlings was similar following a 120-day growout period. Those derived from artificial incubation units and hapas had a greater number of fish in the three largest size categories. A simple cost and return analysis also indicate that fingerling growout of fish from artificial incubation-units and hapas had the highest net profit, although this was not statistically significantly different. Although some advantages may apply to using fish hatched in artificial incubation units and hapas, our work indicates that any of the tilapia hatchery systems are suitable for supplying fingerlings for the growout production of Nile tilapia with little impact on gross yield.

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Table 1. Mean weight and spawning rate of 8-month (treatment I), 1 year-old (treatment II), and 2-year old (treatment III) broodfish used to evaluate the effects of broodstock age/size on tilapia seed production. Values shown as mean ± standard deviation (N = 4 replicates/group)

Treatment	Initial Mean Weight of Male Broodfish (g)	Initial Mean Weight of Female Broodfish (g)	Spawning Rate (%)
I – 8 month-old broodfish	116.2 ± 4.2^{a}	137.6 ± 10.5^{a}	41.0 ± 12.6^{a}
II – 1 year-old broodfish	164.1 ± 19.3^{b}	163.3 ± 3.9^{b}	41.0 ± 8.1^{a}
III – 2 year-old broodfish	488.2 ± 29.4^{c}	331.4 ± 11.8^{c}	24.4 ± 17.8^{a}

There were no significant differences in variables measured among groups (P > 0.05) as indicated by similar superscript letters.

Table 2. Total number of eggs produced and hatching rate derived from 8-month (treatment I), 1 year-old (treatment II), and 2-year old (treatment III) broodfish. Values shown as mean ± standard deviation (N = 4 replicates/group)

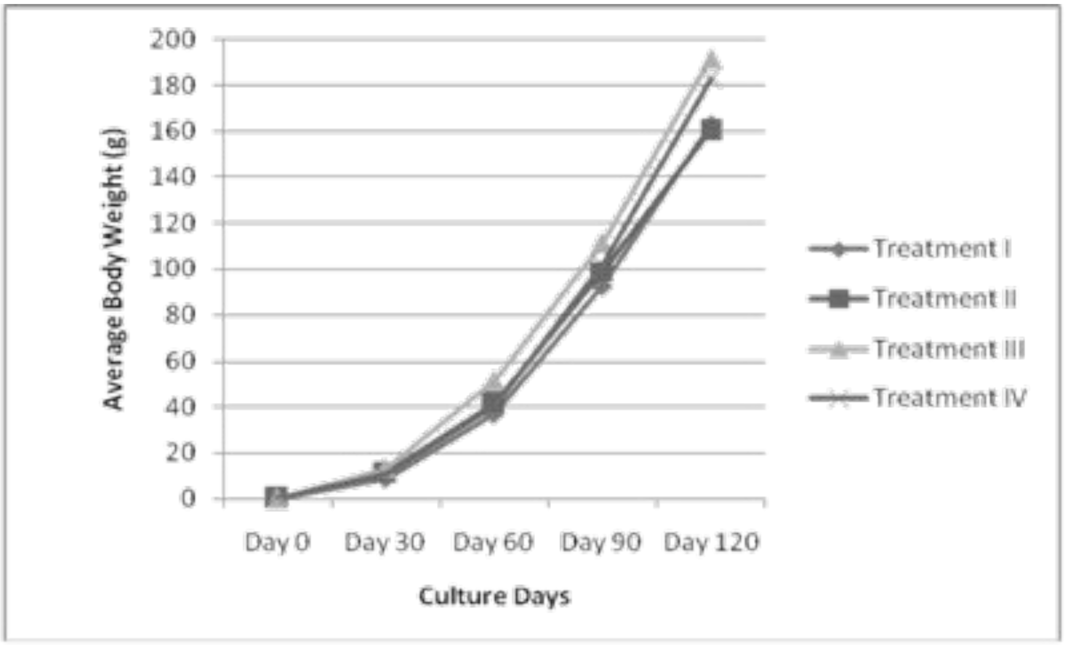
Treatment	Number of eggs produced	Hatching rate (%)
I – 8 month-old broodfish	7040 ± 1729^{a}	49.5 ± 0.0^{a}
II – 1 year-old broodfish	6839 ± 869^{a}	54.8 ± 0.0^{b}
III – 2 year-old broodfish	6875 ± 4303^{a}	65.4 ± 0.0^{c}

There were no significant differences in variables measured among groups (P > 0.05) as indicated by similar superscript letters.

Table 3. Seed production (number of hatched eggs + swim-up fry + fry) derived from 8-month (treatment I), 1 year-old (treatment II), and 2-year old (treatment III) broodfish. Values shown as mean ± standard deviation (N = 4 replicates/group)

Treatment	Number of hatched-eggs	Number of swim-up fry	Number of Fry	Total seed production
I – 8 month-old broodfish	3499 ± 859^{a}	4340 ± 2147^{a}	2241 ± 921^{a}	10079 ± 2507^{a}
II – 1 year-old broodfish	3748 ± 476^{a}	2229 ± 1976^{a}	2305 ± 1574^{a}	8281 ± 2627^{a}
III – 2 year-old broodfish	4496 ± 2814^{a}	3579 ± 3952^{a}	1389 ± 1637^{a}	9464 ± 7508^{a}

There were no significant differences in variables measured among groups (P > 0.05) as indicated by similar superscript letters.



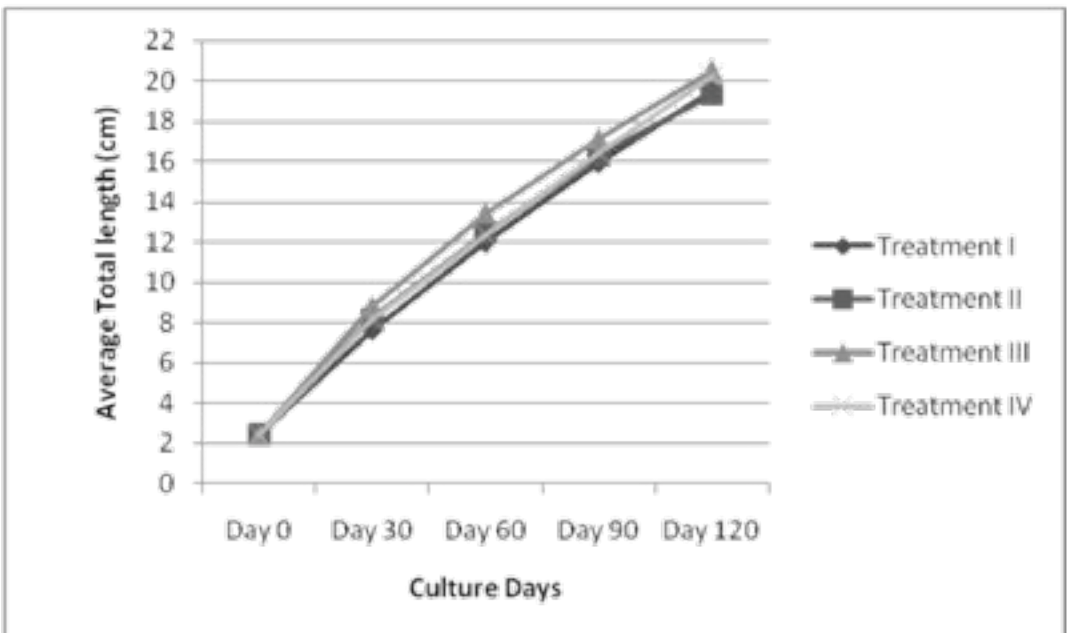


Figure 1. Mean body weight (top) and total length (bottom) of fingerlings produced from different aged broodstock and grown out for a 120-day culture period in earthen ponds. Nile tilapia fingerlings were produced from 8-month old (Treatment I), 1-year old (Treatment II), 2-year old (Treatment III), and a combination (Treatment IV) of broodstock ages (N = 3 ponds/treatment).

Table 4. Summary data of performance variables of Nile tilapia fingerlings derived from broodfish of different ages and grown out for 120 days in earthen ponds. Mean ± standard error.

Parameter	Broodstock Age 8–month old	Broodstock Age 1-year old	Broodstock Age 2-year old	Broodstock Age Combination
Initial Average Body Weight (g)	0.192	0.196	0.208	0.199
Final Average Body Weight (g)	162.855 ± 28.5	160.401 ± 1.3	191.458 ± 33.6	182.611 ± 33.5
Initial Average Total Length (cm)	2.4	2.4	2.4	2.4
Final Average Total Length (cm)	19.5 ± 1.1	19.4 ± 0.2	20.5 ± 1.1	20.2 ± 1.1
Daily Gain in Weight (g/day)	1.356 ± 0.24	1.335 ± 0.01	1.594 ± 0.28	1.520 ± 0.28
Daily gain in Total length (cm/day)	0.143 ± 0.010	0.141 ± 0.001	0.151 ± 0.009	0.149 ± 0.009
Specific Growth Rate (%)	5.611 ± 0.14	5.589 ± 0.01	5.679 ± 0.14	5.675 ± 0.16
Survival Rate (%)	61.3 ± 22.9	61.0 ± 8.2	53.8 ± 4.6	70.0 ± 14.1
Extrapolated Yield per Hectare (kg/ha)	3667.3 ± 689.3	3719.3 ± 365.5	4045.3 ± 1039.8	4472.7 ± 619.1
Extrapolated Feed Consumed per Hectare (kg/ha)	5353.2 ± 172	5506.7 ± 169	6315.4 ± 747	5692.5 ± 590
Feed Conversion Ratio (kg feed/kg weight gain)	1.5 ± 0.4	1.5 ± 0.1	1.6 ± 0.2	1.3 ± 0.1
Feed Conversion Efficiency (%)	68.7 ± 14.7	67.4 ± 6.3	63.3 ± 9.2	78.3 ± 4.4

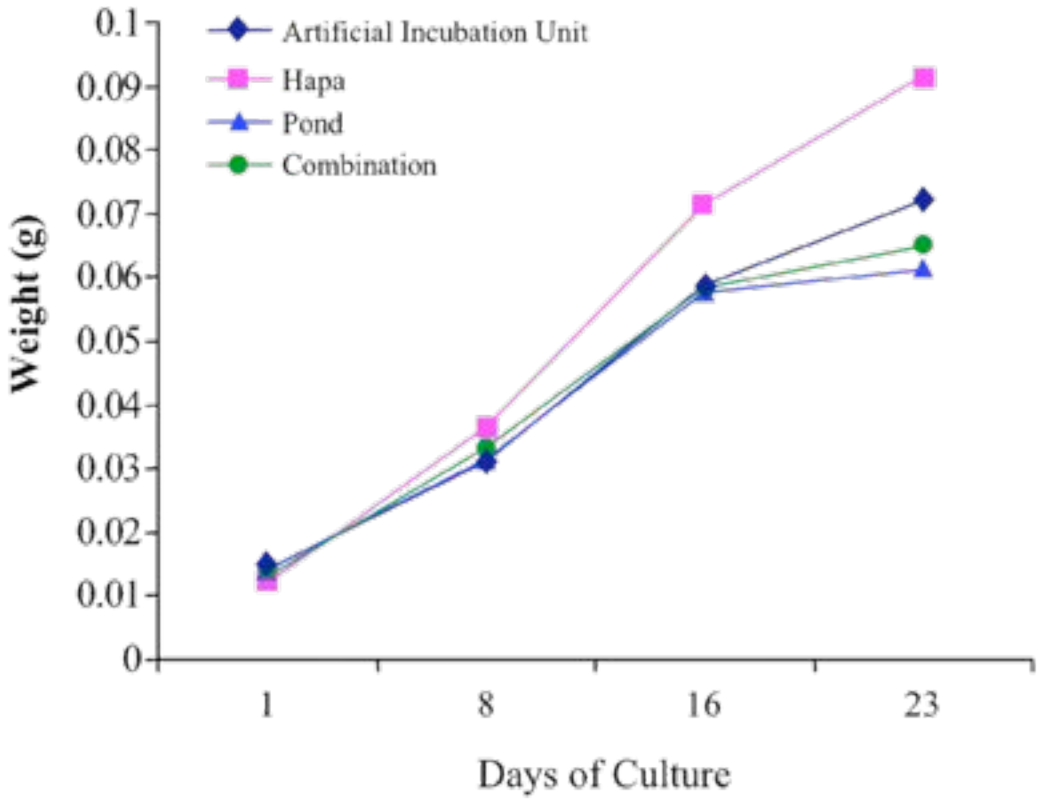


Figure 2. Changes in mean body weight of fry produced from different hatching systems and grown for 23 days in nursery hapas. Fry were produced from artificial incubation units, hapas, ponds, or a combination of the three. (N = 3 replicates/group).

Table 5. Initial and final mean length and weight of fry produced from different hatching systems (artificial incubation units, hapas, ponds, and a combination of the three) and reared for 23 days in nursery hapas. (N = 3 replicates/group).

Treatment	Initial Length (mm)	Final Length (mm)	Initial Weight (g)	Final Weight (g)
I – incubation-hatched fry	8.45	17.41	0.014	0.071
II – hapa-hatched fry	8.40	17.30	0.012	0.081
III – pond-hatched fry	8.30	17.40	0.014	0.068
IV – combination of hatched fry	8.45	17.57	0.013	0.072

Treatment groups did not differ at 5% level of significance.

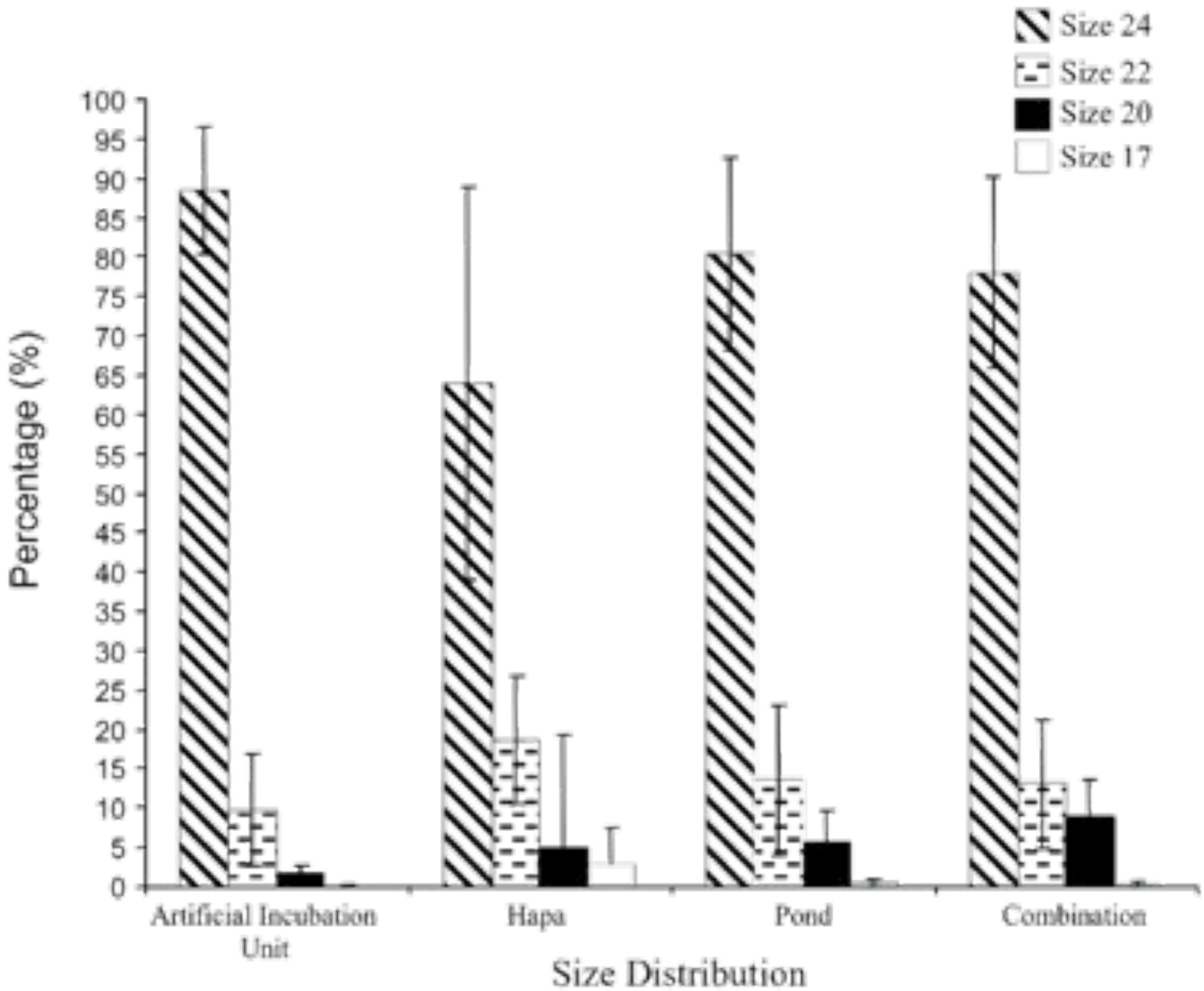
Table 6. Mean growth performances of fry produced from different hatching systems (artificial incubation units, hapas, ponds, and a combination of the three) and reared and sex reversed for 23 days in nursery hapas. Values represent mean ± standard deviation (N = 3 replicates/group).

Treatment	Gain in Length (mm)	Gain in Weight (g)	Specific Growth Rate (%)
I – incubation-hatched fry	8.96 ± 1.47	0.06 ± 0.02	6.97 ± 1.41
II – hapa-hatched fry	8.90 ± 1.80	0.07 ± 0.03	8.70 ± 1.34
III – pond-hatched fry	9.10 ± 1.52	0.05 ± 0.02	6.32 ± 1.14
IV – combination of hatched fry	9.12 ± 1.12	0.06 ± 0.01	6.92 ± 0.98

There were no differences in variables among treatment groups at 5% level of significance.

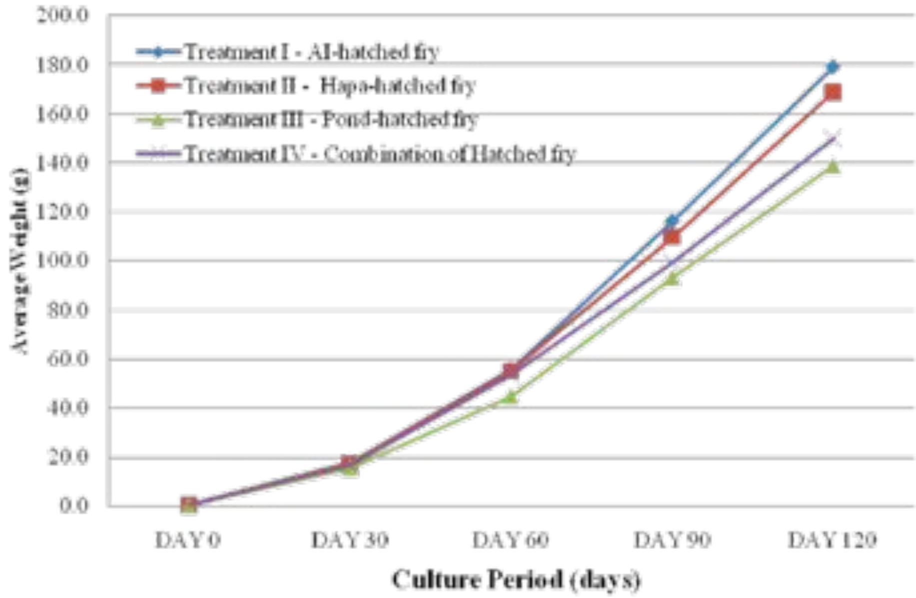
Table 7. Mean percent survival of fry produced from different hatching systems (artificial incubation units, hapas, ponds, and a combination of the three) and reared and sex reversed for 23 days in nursery hapas. Values represent mean ± standard deviation (N = 3 replicates/group).

Treatment	Survival (%)
I – incubation-hatched fry	92.03 ± 1.47^{a}
II – hapa-hatched fry	65.19 ± 1.12^{b}
III – pond-hatched fry	76.50 ± 1.80^{ab}
IV – combination of hatched fry	72.81 ± 1.52^{b}



Treatment means with the different superscript letters are significantly different from each other ($P < 0.05$).

Figure 3. Changes in mean body weight of fry produced from different hatching systems and grown for 23 days in nursery hapas. Fry were produced from artificial incubation units, hapas, ponds, or a combination of the three. Mean ± standard deviation, N = 3 replicates/group. Fry size ranges include size 24 (0.06-0.09 g), size 22 (0.10-0.14 g), size 20 (0.16 - 0.20 g), and size 17 (0.25-0.30 g).



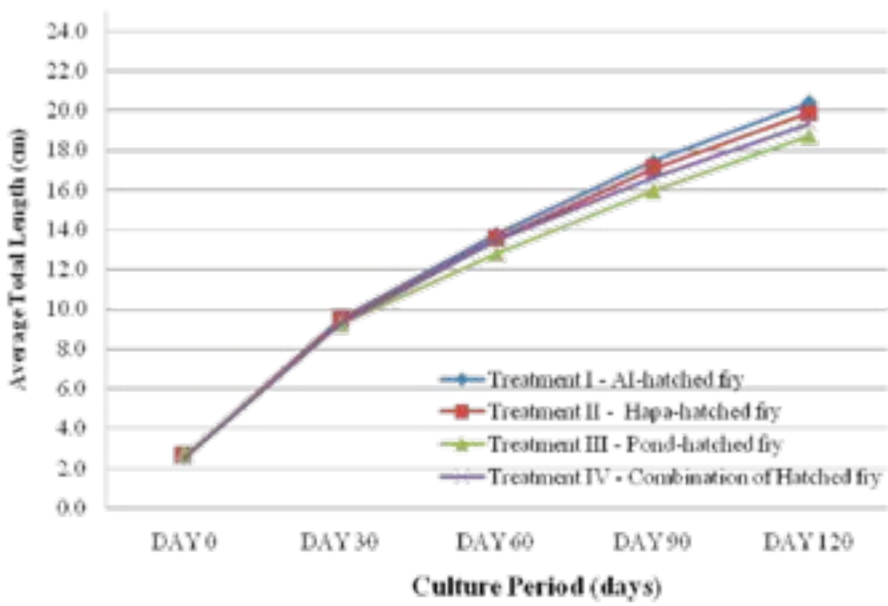


Figure 4. Mean body weight (top) and total length (bottom) of fingerlings produced from fry hatched in different systems and grown out for a 120-day culture period in earthen ponds. Fingerlings were derived from fry hatched in artificial incubation units (Treatment I), hapas (Treatment II), ponds (Treatment III), or a combination of the three (Treatment IV). (N = 3 ponds/treatment).

Table 8. Performance variables of Nile tilapia fingerlings produced from fry hatched in different systems and grown out for a 120-day culture period in earthen ponds. Fingerlings were derived from fry hatched in artificial incubation units, hapas, ponds, or a combination of the three systems. Mean ± standard deviation (N = 3 ponds/group).

Performance	**Treatment**			
	Artificial Incubation Units	Hapa	Pond	Combination
Initial Mean Weight (g)	0.292 ± 0.011^{a}	0.308 ± 0.014^{ab}	0.320 ± 0.017^{b}	0.271 ± 0.005^{ab}
Final Mean Weight (g)	179.256 ± 42.3^{a}	168.945 ± 48.6^{a}	138.871 ± 17.3^{a}	150.042 ± 14.7^{a}
Daily Gain in Weight (g day^{-1})	1.492 ± 0.352^{a}	1.405 ± 0.405^{a}	1.155 ± 0.144^{a}	1.248 ± 0.122^{a}
Initial Mean Length (cm)	2.6 ± 0.058^{a}	2.6 ± 0.115^{a}	2.7 ± 0.115^{a}	2.5 ± 0.100^{a}
Final Mean Length (cm)	20.4 ± 1.6^{a}	19.9 ± 1.8^{a}	18.7 ± 0.7^{a}	19.3 ± 0.6^{a}
Daily Gain in Length (cm day^{-1})	0.149 ± 0.013^{a}	0.144 ± 0.017^{a}	0.134 ± 0.007^{a}	0.140 ± 0.004^{a}
Specific Growth Rate (%)	5.333 ± 0.2^{a}	5.235 ± 0.3^{a}	5.058 ± 0.2^{a}	5.264 ± 0.1^{a}
Extrapolated Feed Consumed (kg ha^{-1})	7055 ± 1258.6^{a}	6820 ± 1420.5^{a}	5853 ± 123.7^{a}	6497 ± 375.2^{a}
Feed Conversion Ratio	2.0 ± 0.153^{a}	2.1 ± 0.153^{a}	2.1 ± 0.252^{a}	2.2 ± 0.115^{a}
Feed Conversion Efficiency	50.4 ± 3.980^{a}	48.9 ± 3.686^{a}	47.3 ± 5.021^{a}	46.0 ± 2.230^{a}
Gross Fish Yield (kg pond^{-1})	194.533 ± 30.3^{a}	189.874 ± 37.7^{a}	149.757 ± 43.2^{a}	174.448 ± 9.4^{a}
Extrapolated Gross Fish Yield (kg ha^{-1})	3890.7 ± 605.5^{a}	3797.5 ± 754.0^{a}	2995.1 ± 864.4^{a}	3489.0 ± 187.6^{a}
Survival (%)	56.6 ± 8.1^{a}	58.6 ± 15.1^{a}	56.3 ± 22.5^{a}	59.3 ± 1.7^{a}

Treatment means with the different superscript letters are significantly different from each other ($P < 0.05$).

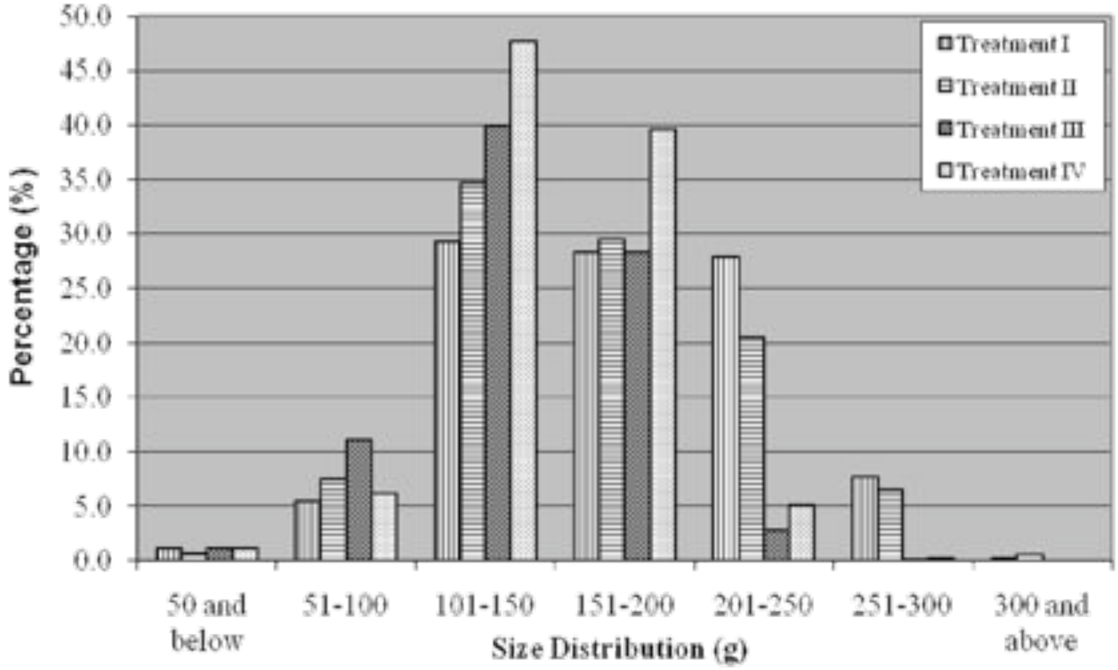


Figure 5. Size distribution of fingerlings produced from fry hatched in different systems and grown out for a 120-day culture period in earthen ponds. Fingerlings were derived from fry hatched in artificial incubation units (Treatment I), hapas (Treatment II), ponds (Treatment III), or a combination of the three (Treatment IV). (N = 3 ponds/treatment).

Table 9. Simple cost and return analysis per hectare of Nile tilapia fingerlings produced from fry hatched in different systems and grown out for a 120-day culture period in earthen ponds. Fingerlings were derived from fry hatched in artificial incubation units, hapas, ponds, or a combination of the three systems. Values are in Philippine pesos (PhP).

Item	**Treatment**			
	I	II	III	IV
Gross Return (PhP)	233,442.00	227,850.00	179,706.00	209,340.00
Cost (PhP)				
Fingerlings	18,000.00	18,000.00	18,000.00	18,000.00
Commercial Fertilizers				
Ammonium Phosphate	3,676.66	3,007.20	2,674.26	3,340.14
Urea	6,858.84	5,610.78	4,988.58	6,232.98
Commercial Feeds	176,400.00	170,500.00	146,300.00	162,400.00
Total Cost	204,935.50	197,117.98	171,962.84	189,973.12
Net Returns (PhP)	28,506.50	30,732.02	7,743.16	19,366.88
Assumptions: Stocking density	4 pcs m^{-2}			
Price of fingerlings	PhP 0.45 pc^{-1}			
Price of commercial fertilizers				
Ammonium Phosphate	PhP 35.80 kg^{-1}			
Urea	PhP 36.60 kg^{-1}			
Price of commercial feeds	PhP 25.00 kg^{-1}			
Price of marketable tilapia	PhP 60.00 kg^{-1}			