Improving genetic quality of cultivated aquatic species under a breeding program: Case study of first generation (G1) population of red tilapia (*Oreochromis* spp)

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**Abstract.** A body weight based selection protocol is the most common practice in the genetic improvement programs for aquaculture species. It might be one of the criteria to be considered in the aquatic resources management scheme. This experiment aimed to evaluate the genetic enhancement of selected first-generation (G1) of red tilapia. Fish were bred under fullsib mating design at hapa of 2x2 m². The communal growing out of fingerlings was carried out in an earthen pond for 120 days. The stocking density of fingerlings was 7 fish per m². Fish were fed with commercial floating fish feed at a rate of 5-10% of biomass twice a day. The results showed that the population of males and females of red tilapia in the first generation (G1) grew faster than the previous generation (G0). The selection response values were 19.52% and 12.05% for male and female populations, respectively. The heritability values in male and female red tilapia populations were in the medium category with a value of 0.33 and 0.25, respectively. The results showed that the breeding program increased the genetic quality of fish in terms of body weight based growth in the first generation of red tilapia.

**Keywords:** cultivated species; growth; heritability; red tilapia; selection response

1. Introduction

Tilapia is a freshwater fish that is believed to have evolved from marine waters [1]. It is not surprising that most tilapia can tolerate various levels of salinity and can grow and reproduce normally in brackish water. In fact, some species are reported to be able to grow and reproduce at very high salinity. Several tests reported that different tilapia species have different resistance to salinity. According to El Sayed [2], several factors affect the ability of fish to tolerate salinity including fish species, strain, size, adaptation time, methods, and environmental factors. Improper fish broodstock management that is often associated with high levels of inbreeding has resulted in a reduction in the productivity of cultured populations under various commercial settings [3, 4].

In order to increase national fish production and provide new genetic sources, in 1969, tilapia was introduced from Taiwan to Indonesia. In 1981, tilapia which was known as red NIFI, was introduced from the Philippines. During the period from 2005 to 2014, some strains of red tilapia had been developed in Indonesia, including *Larasati*, *Janti*, *Prima* and *Sa* strains. Tilapia aquaculture activities are growing rapidly with market demand increase consistently.
The formation of superior tilapia can be done through a selection program. The selection program has had a positive impact on farmers by increasing the growth rate of fish [5] total yields [6], salinity resistance [7] and resistance to Streptococcus [8]. In general, the breeding program applied to tilapia is family selection. During the last 40 years, there were many family-based fish breeding programs with a genetic gain higher than 12% per generation [9]. A number of selection experiments and breeding programs aiming at increased growth rates in ponds have been conducted for Nile tilapia (O. niloticus) [10–12]. Nile tilapia was a species that was heavily involved in mass and family-based breeding programs in aquaculture, with a remarkable genetic gain over the last few decades. Several selection programs on tilapia to increase growth have been carried out through mass selection, but the results are low. In contrast, the results of family selection showed that there was an increase in good growth response in tilapia. Genetic improvement programs have contributed to a dramatic increase in production of Nile tilapia [13, 14].

Improvement of red tilapia populations to obtain new strain will be successful if there is a wide genetic diversity in the population due to differences in genotypes between fish. Genetic parameters values such as heritability and genetic correlation are important parameters in genetic improvement programs, as they are used as a basis for selection. This study aimed to evaluate the genetic improvement of first-generation red tilapia as one of the cultivated aquatic species under the selection program.

2. Materials and methods
This activity was carried out at Research Institute for Fish Breeding, Sukamandi (Indonesia) in May-October 2019. The formation of the first-generation (G1) red tilapia population was carried out using selected broodstock of the basic population of red tilapia (G0). The spawning method used was a full-sibling design.

The formation of the first generation red tilapia (G1) population was carried out through natural spawning. Spawning was carried out using a male to female ratio of 1:3. Each family was spawned in happa sized of 2x1 m² which was placed in a 25 m² pond. After 7 days of mating, fertilized eggs were collected from the mouth of the female and immediately transferred to hatching jars for artificial incubation. Fry was normally hatched after 5 to 7 days. As soon as yolk-sac was absorbed the larvae were then reared in a 2x2x1 m³ happa for 60 days with a stocking density of 75 fish / m².

During nursery, the larvae were fed with 30-40% protein level commercial feed under ad libitum feeding with a frequency of 3 times a day. When the fingerlings reached an average weight of 5–10 g, about 50 individuals per family were randomly sampled and individually identified, by passive integrated transponder (PIT) tags. While the tagging process, the identification number, body weight (BW), standard length (L), body depth (D), and body width (W) were also recorded. After conditioning for about 3 days in holding tanks without feeding, the tagged fingerlings of the representatives of each family were pooled together and were sent to communal grow-out testing in earthen ponds and or cages. Dead fish were recorded and replaced by new fingerlings from the same family. The rearing (grow out) stage was carried out until the fish reach the size of the prospective broodstock (i.e. 150-200 g /fish) for 120 days. Feeding was applied 3 times a day (morning, afternoon and evening) with a declined ratio of 10% of fish biomass in the first month to 5% of fish biomass in the last month. The feed had a protein content of ± 30%.

At the end of the maintenance, a selection process was carried out on the growth character. The selection process was differentiated between male and female because male and female tilapia had different growth rates. From each population, a random sample of 100 individuals was taken, and then the weight was measured so that the size distribution data were obtained which were then sorted (sorted) from the smallest to the largest value. Based on the sorted size distribution data, a minimum limit of the size of the fish to be selected was set, namely 10% male individuals with the best phenotypic performance of the population. The same procedure was applied for selecting prospective broodstock of individual females. Based on the minimum threshold size that has been obtained, the entire population was selected. Prospective male parents are selected based on the criteria for male
size while female candidates are selected based on the criteria for female size. The same selection and mating procedures were repeated in all generations (First generation) during the breeding program. Individuals selected as prospective broodstock are reared in the brood maturation pool.

The observed parameters included growth rate (weight and length), absolute growth, daily growth rate (DGR), feed conversion ratio (FCR), specific growth rate (SGR), Survival rate, response to selection, and heritability.

3. Data analysis
Statistical analysis to examine differences in the average weight of individuals, survival rates and total yield biomass between selected G1 seed populations and G0 seeds was carried out using the t-test at the level of $\alpha = 0.05$. Individual average weight data were also used to analyze values, absolute growth, daily growth rate (DGR), feed conversion (FCR), specific growth rate (SGR), selection response from population G0 to G1 and heritability values for the real meaning of population growth characters selected by population G0. Data of selection response and real heritability of red tilapia populations were analyzed descriptively.

a. Absolute Growth
$$\Delta W = W_t - W_0$$
$$\Delta L = L_t - L_0$$

b. Specific growth rate
$$SGR = \frac{(\ln W_t - \ln W_0)}{t} \times 100$$

c. Daily Growth rate
$$GR = \frac{W_{t} - W_0}{t}$$

d. Feed conversion ratio
$$FCR = \frac{F}{W_t - W_0}$$

e. Survival Rate
$$SR = \frac{N_t}{N_0} \times 100$$

f. Selection response (R) was performed by this following formula:
$$R = X(F_1)' - X(F_0)$$

where:
X (F1) = Average weight of G1
X (F0) = Average weight of G0

And, the percentage of selection response was performed by following formula:
$$R \% = \frac{R}{W_t}$$

where:
R (%) = percentage of selection response
R = selection response
WT = average population of previous population
g. Heritability was calculated by formula:

\[ h^2 = \frac{R}{S} \]  

where:
S = differential selection G0
R = response to selection [15]

4. Results and discussion
The growth rate test was used to see the growth character selection response indicated by the average weight of individuals between generations. In this activity, what you want to see was the selection response of G0 red tilapia broodstock to the growth rate of G1 progeny. Based on Figure 1 and Figure 2, it was known that the growth pattern of length and weight of the red tilapia population of the basic population (G0) and the population of the first generation (G1) of the male and female subpopulations. Male and female sub-populations of G1 red tilapia have better growth in length and weight than the control population from the beginning to the end of the rearing. This shows an increase in performance in the F1 population compared to the previous generation. The difference in performance between the two populations of red tilapia was a reflection of the genetic improvement passed on from parent to young as a result of the selection program. Growth was one of the factors that become indicators of success in fish farming activities. In addition, the evaluation of growth performance, especially in weight characters, can be used as a determinant of whether the selective breeding program was progressing through the selection method. According to Warwick et al. [16] increasing the genetic quality (genetic gain) of the parent through selection will change the average population of the offspring for the better. One of the factors that influence growth was the internal factor. Factors include heredity, sex, age, and generally difficult to control. Heredity may be controlled by selecting to look for good growth fish [17].

Growth parameters namely absolute growth, specific growth rate and daily growth showed that the first generation red tilapia showed higher yields than G0 red tilapia (table 1). The specific growth rate and daily growth rate of G1 red tilapia in the male population were 3.48% and 20.05% higher than that of G0 red tilapia. Likewise in the female population, the value of specific growth rate and daily growth rate of red tilapia G1 were 3.27% and 12.58% higher than G0 red tilapia. The high growth of tamarind also has a good survival value, where the resulting survival rate was around 70%. According to Tave [18], the low growth rate of a fish population was caused by inbreeding depression. In addition, inbreeding depression can also cause abnormalities and high asymmetries, premature sexual maturity and reduce fitness. These results are consistent with the research of Robisalmi et al. [19] that the value of specific growth rate and daily growth rate of selected red tilapia in brackish water was known to be higher than control population of red tilapia, respectively 1.47 ± 0.14% weight / day and 1.01 ± 0.21 g / day. El Zaeem et al. [20] reported that red tilapia reared at a salinity of 32 ppt for 105 days produced a specific growth rate of 3.70% / day while red tilapia raised in marine KJA for 126 days had a daily growth rate of 1.13–1.71 g / days [21, 22].

In this study, it was found that the male red tilapia sub-population was able to grow faster than the female population in both the first and second generation of red tilapia. This was because the energy produced from feed in male fish can be fully utilized for growth, while in female fish some of the energy from feed in addition to growth was used for reproduction, gonad development, and egg production. In addition, it was also known that many female fish that have matured gonads were indicated by red genital organs and yellow eggs that come out of the reproductive organs when sequencing and the presence of a number of eggs incubated by the female parent. Popma and Masser [23] stated, Biologically male tilapia, the growth rate was faster because it does not prepare for the formation of egg yolk, vitellogenesis, and egg maturation compared to female tilapia. In addition, the growth of tilapia was influenced by the sex of the fish which also depends on the ambient temperature [24]. The growth pattern of males and females was different in tilapia, this difference occurs because of the social interaction between fish and the environment. Aksungur et al. [25] stated that there were
indications related to fish social interactions, where feed competition and space for movement can have a negative effect on fish growth. Studies on sexual dimorphism in species and strains of tilapia suggest that strategies should be specifically tailored for males and females in order to achieve optimal results [26]. The difference in ranking among groups was possibly due to the distinct genetic components, such as additive and non-additive genetic effects of males and females heterosis.

**Figure 1.** The length Growth pattern of male (a) and female (b) red tilapia G0 and red tilapia G1 reared in brackish water pond for 120 days.
Figure 2. The weight growth pattern of male (a) and female (b) red tilapia G0 and red tilapia G1 reared in brackish water pond for 120 days.

The value of growth increase in weight character was a value that indicates a genetic improvement in the next generation. This value was calculated by comparing the weight difference between the red tilapia population G1 and the red tilapia population G0 (Table 2). According to Tave [18], the phenotype was any measurable characteristic possessed by an organism and was the result of the interaction between the genotype and the environment and was a visible trait. In addition, the real heritability value of the weight character of red tilapia G1 was also calculated by comparing the selection response value and the value of the selection differential (G0). The breeding populations of the red tilapia had much greater genetic variation in growth additives in Nile tilapia [27] and blue tilapia [28].
Table 1. Growth and survival of male and female red tilapia G1 and red tilapia G0.

| Parameter          | Male Population | Female Population |
|--------------------|-----------------|-------------------|
|                    | red tilapia GO  | red tilapia G1    |
|                    | red tilapia G0  | red tilapia G1    |
| Initial length (cm)| 7.56            | 7.68              |
| Final length (cm)  | 21.94           | 22.59             |
| Initial weight (g) | 7.95            | 8.50              |
| Final Weight       | 194.02          | 231.89            |
| Length gain (g)    | 14.38           | 14.91             |
| Weight gain (g)    | 172.09          | 209.30            |
| DGR (g/days)       | 1.55            | 1.60              |
| SGR (%/days)       | 2.66            | 2.76              |
| Survival (%)       | 67.40           | 69.00             |

Table 2. The individual weight of red tilapia G1, red tilapia G0, response to selection, selection differential and heritability of red tilapia at brackish water pond for 120 days period.

| Populations | Individual weight of red tilapia G1 | Individual weight of red tilapia G1 | Response to selection (g) | Response to selection (%) | Selection differential F0 | Heritability (h^2) |
|-------------|------------------------------------|------------------------------------|--------------------------|--------------------------|--------------------------|-------------------|
| Male        | 231.89                             | 194.02                             | 37.86                    | 19.52                    | 71.16                    | 0.53              |
| Female      | 189.00                             | 168.67                             | 20.33                    | 12.05                    | 58.53                    | 0.35              |
| Average     | 210.44                             | 181.35                             | 29.10                    | 15.78                    | 64.84                    | 0.44              |

The selection response value in the G1 red tilapia population reached 19.52% for the male sub-population and 12.05% for the female sub-population, indicating the success of selection from the previous generation (G0). Genetic progress can be used as a guide in determining selection activities. If the generic progress value, the expectation of a character was high, it means there was a big chance for improvement of the character through selection. Conversely, if the expected value of genetic progress was low, then the selection activity on the character concerned can be carried out at one generation to form a uniform population or the selection activity can be stopped because the improvements to be achieved were relatively low. Therefore, to improve the purity and performance of red tilapia, the selection process needs to be continued for the next generation. Hamzah *et al.* [29] the cumulative gain in body weight after three generations of selection was 36.6%, averaging 12.3% per generation (1 year per generation). The substantial genetic gain achieved for body growth was consistent with the moderate to high heritability. Expected genetic progress was a measure in percent of the shift in the mean population value from the population condition to the condition after selection, assuming a differential magnitude. The realized genetic progress achieved in the current red tilapia population was in line with the results of existing research, namely a 15% increase in body weight per generation, as reported in other cultivated species [30–32].

The heritability value of G1 red tilapia in the range of 0.35–0.53 was in the medium and high categories. This value indicates that both genetic and environmental factors play a role in determining the weight character. Heritability values of more than 0.3 indicate that selection in red tilapia was effective, so genetic factors were more dominant in the appearance of fish phenotypes. If the heritability value was lower in the selected character, the selection was relatively less effective due to the phenotype performance was affected by environmental factors rather than the genetic factor. The environmental factors that affected the phenotype were location, fish feed, management, and fish disease. Warwick *et al.* [16] stated that the heritability value which was categorized as medium to high will be more effective and efficient in increasing genetic quality improvement when compared to the selection made at low heritability values. According to Noor [33], selection does not create new genes, but the exploitation of additive genetic variation (VA) will change the frequency of genes to improve
genetic quality qualitatively and quantitatively with the ultimate goal of obtaining superior parents as parents. Heritability values can be classified into three categories, namely low, medium and high. Heritability value was low if the value was between 0–0.20, the medium was between 0.2–0.4, and high for values more than 0.4, while Falconer [15], the h2 value of quantitative characters in fish consists of levels, namely: low (0–0.1), moderate (0.1–0.3) and high (0.3–1.0). The moderate to high heritability for traits obtained in this study were in line with those reported for growth (h2 = 0.42), survival (0.05–0.09) and external color traits (0.14–0.51) in a different population of red tilapia [28]. Compared to those previously reported on the earlier generations of GIFT (0.14–0.34) [12, 34, 35], high heritability estimates for Nile tilapia have also been reported when the common environmental effect was accounted for: 0.38–0.60 [36] or 0.36–0.71 [37]. High heritability values play a major role in increasing the effectiveness of selection. For characters with high heritability, the selection will be more effective because of the small environmental influence, so that genetic factors were more dominant in the appearance of fish phenotypes. For characters with low heritability, the selection will run relatively less effective, because the phenotypic appearance of the fish was more influenced by environmental factors than their genetic factors. High heritability value followed by high-hope genetic progress will further increase the selection success. This was in accordance with the opinion of [38] where heritability will be more useful if it was guided by the standard deviation of phenotypes and the intensity of selection to determine genetic progress or the selection response of a character. In addition, the heritability value in the medium to high category illustrates that genetic factors play a very important role in determining phenotypic diversity, so that it can be maximally utilized in increasing genetic progress through selection programs.

5. Conclusion
The population growth of first generation red tilapia (G1), male and female sub-populations was higher than the basic population of red tilapia (G0). The real heritability value (h2) of weight characters in the red tilapia population, male and female subpopulations were in the medium and high categories with good selection response. The high heritability with a positive selection response indicates that the selection program for red tilapia was still effective and can be continued.

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