Jurnal Sains Akuakultur Tropis
Departemen Akuakultur
Fakultas Perikanan dan Ilmu Kelautan – Universitas Diponegoro
Jl. Prof. Soedarto, SH, Tembalang,Semarang 50275
Telp. (024) 7474698, Fax.: (024) 7474698
Email: sainsakuakulturtropis@gmail.com, sainsakuakulturtropis@undip.ac.id

Performance and Heterosis of Kekar and Kunti Nile Tilapia (Oreochromis niloticus) Hybrid Seed in Salinity Media

Tristiana Yuniarti*, A. H. Condro Haditomo, Satrio Ramadhan Kusuma Jati

Aquacuture Department, Faculty of Fisheries and Marine Science, Diponegoro Universitity, Jl. Prof. H. Soedarto, S.H, Tembalang, Semarang, Jawa Tengah-50275, Indonesia, Telp/Fax.+6224 7474698
* Corresponding author: yuni_bbats@yahoo.com

Abstract

Nile tilapia is one of the leading freshwater fish commodities. The development of Nile tilapia aquaculture is currently being carried out in saline media. Therefore, it is necessary to identify Nile tilapia with the best tolerance when developed in brackish water. Seed quality can be maintained or improved through hybridization. Kekar and Kunti Nile tilapia are Nile tilapia produced through genetic breeding. This study aimed to determine the performance and heterosis values of Nile tilapia seed resulting from crosses between Kekar and Kunti strains reared in saline media. This study used an experimental method with a Completely Randomized Design (CRD) consisting of four treatments and three replications, namely P1 (♂ Kunti × ♀ Kunti), P2 (♂ Kunti × ♀ Kekar), P3 (♂ Kekar × ♀ Kunti), and P4 (♂ Kekar × ♀ Kekar). A total of 25 fish per aquarium, measuring 4–5 cm, were reared in freshwater and the salinity was increased to 15 ppt. During rearing, seed feed containing 30% protein was provided using the ad satiation feeding method. The observed parameters included Total Feed Consumption (TFC), Food Conversion Ratio (FCR), Feed Utilization Efficiency (FUE), absolute weight, absolute length, Specific Growth Rate (SGR), and Survival Rate (SR). Statistical analysis showed that different genetic sources, namely Kekar and Kunti Nile tilapia and their crosses, significantly affected TFC, FCR, growth, and survival of seed reared in saline media. Treatment P4 (♂ Kekar × ♀ Kekar) provided the best results compared with the other treatments, with TFC of 153.80±0.18 g, FCR of 0.91±0.11, FUE of 90.31±4.67%, absolute weight of 2.22±0.18 g, absolute length of 3.22±0.45 cm, SGR of 2.44±0.21%/day, and SR of 90.67±2.31%. Heterosis values for several parameters were negative, indicating that P4 seed (♂ Kekar × ♀ Kekar) had better performance than the hybrid seed treatments, namely P2 (♂ Kunti × ♀ Kekar) and P3 (♂ Kekar × ♀ Kunti).

Keyword : growth, heterosis, hybrid, performance, seed, tilaphia

INTRODUCTION

Nile tilapia production has increased rapidly from year to year. Domestic and export demand for Nile tilapia has also increased. Nile tilapia production in 2023 in the grow-out sector amounted to 1,368,542 tons and in the seed production sector amounted to 44,172,165 thousand fish (Ministry of Marine Affairs and Fisheries, 2025). Nile tilapia contains protein, fat, calcium, magnesium, potassium, phosphorus, sodium, vitamin B-6, and vitamin B-12 (U.S. Department of Agriculture, 2018).

Nile tilapia has euryhaline characteristics, giving it very good potential for development in brackish water/saline media. The Salina Nile tilapia strain in the grow-out phase has advantages including optimal growth at salinities of 20–25 ppt, high survival rates (78.79–86.02%), low feed conversion ratios (0.80–0.83), and resistance to Streptococcus disease Kepmen Kelautan dan Perikanan no 22 tahun 2014)

Hybridization or controlled crossing is an effort to produce superior-quality seed in order to overcome genetic quality decline. The mechanism of hybridization is to combine superior traits from two parental

populations. The expected result is hybrid vigor or offspring with superior quality compared with both parents. The principal objectives of crossbreeding between fish species/breeds are to harness heterosis, capitalize on breed complementarity, enhance overall fitness and reproductive performance, and mitigate the accumulation of inbreeding resulting from prolonged selection, thereby preventing the detrimental effects associated with inbreeding depression (Bartley *et al*., 2000; Soudy *et al*, 2026). Kunti Nile tilapia is GIFT F3 Nile tilapia produced through individual selection by PBIAT Janti in 2008 and subsequently known as Kunti Nile tilapia (Apriliza, 2012). Kunti Nile tilapia is currently suspected of having experienced genetic decline compared with when it was first produced. Kekar Nile tilapia is the result of crossing JICA Nile tilapia, Wanayasa Nile tilapia, and local Sidoarjo Nile tilapia, conducted by Kartoyo in 2007 (Nurmilasari, 2024). The Kekar strain is known for its "deep-bodied" shape, relatively fast growth rate, and good performance in intensive culture systems, making it suitable as a source of growth genes (Asih, 2022). The Kunti strain was developed as a broodstock strain with reproductive stability, seed uniformity, and relatively high tolerance to suboptimal conditions, making it suitable as a source of environmental-resistance genes (Prayuda et al., 2017). The genetic combination of Kekar and Kunti has the potential to produce offspring that grow rapidly 1 while being more tolerant of high salinity.

MATERIALS AND METHODS

This research was conducted at the Laboratory of the Faculty of Fisheries and Marine Science, Diponegoro University, Semarang. The research was conducted from March 18 to April 17, 2026. The equipment used in this study consisted of 50×30×30 cm aquariums, aerators, aerator hoses, air stones, thermometers, refractometers, DO meters, pH meters, digital scales, rulers, fish nets, buckets, polynets, containers, and water hoses. The materials used in this study consisted of Kekar and Kunti Nile tilapia seed and seed resulting from crosses between Kekar and Kunti Nile tilapia, 35 days old and 4 cm in size, freshwater, seawater, potassium permanganate, and commercial feed with the trade name PF 1000. About 300 seeds from PBIAT Klaten used in this research. This study used an experimental method with a Completely Randomized Design (CRD). The study consisted of four treatments, each replicated three times. The treatments used were as follows: P1: Nile tilapia seed from spawning of ♂ Kunti × ♀ Kunti; P2: Nile tilapia seed from crossing of ♂ Kunti × ♀ Kekar; P3: Nile tilapia seed from crossing of ♂ Kekar × ♀ Kunti; and P4: Nile tilapia seed from spawning of ♂ Kekar × ♀ Kekar.

Research Procedure

The containers and equipment used were cleaned and sterilized using potassium permanganate and rinsed with clean water until no chemical residue remained. The containers were then filled with freshwater to 80% of their volume. The initial salinity was adjusted to 0 ppt, and aeration was provided for 24 hours before stocking to stabilize the media conditions. Seed from the four treatments (P1, P2, P3, and P4) was selected to obtain homogeneous sizes. Each aquarium was stocked with 25 fish with a water volume of 36 L. The seed was acclimatized by placing it in plastic bags and allowing the bags to float for 15–30 minutes to adjust the temperature, then gradually adding aquarium water to the bags for adaptation to the initial salinity (0 ppt). After acclimatization, the seed was released into each aquarium according to the treatment and replication. The fish were maintained at 0 ppt salinity for 1 full day to ensure proper initial adaptation. Subsequently, salinity was increased by adding seawater that had been diluted in water evenly by 3 ppt every 24 hours until the treatment salinity was reached, referring to the acclimatization method used by Salim *et al*. (2016). This process was conducted for 5 consecutive days until salinity reached 15 ppt. Thereafter, salinity was maintained at 15 ppt until the end of the 24-day rearing period. Seed was fed using the ad satiation feeding method, twice daily in the morning and afternoon. Aeration was continuously provided for 24 hours to maintain dissolved oxygen levels in the water. Water quality parameters such as temperature, pH, DO, and salinity were observed and recorded every day in the morning and afternoon for daily water-quality monitoring

Variables

1. Total Feed Consumpsion (TFC)
   According to Pereira et al. (2007), total feed consumption can be calculated using the following formula:
   $$TFC = F1 - F2$$
   Description: TFC = total feed consumption; F1 = initial feed amount (g); F2 = remaining feed amount (g).
2. Feed Conversion Ratio (FCR)

According to Tacon (1987), feed conversion ratio can be calculated using the following formula

$$FCR = F / (Wt + D) - Wo$$

Description: FCR = feed conversion ratio; Wo = test-animal weight at the beginning of the study (g); Wt = test-animal weight at the end of the study (g); D = weight of dead fish (g); F = weight of feed consumed

3. Feed Utilization Efficiency (FUE)

According to Tacon (1987), feed utilization efficiency can be calculated using the following formula:

$$FUE = Wt - Wo / F\ x\ 100\%$$

Description: FUE = feed utilization efficiency (%); Wt = total weight of test fish at the end (g); Wo = total weight of test fish at the beginning of the study (g); F = amount of feed consumed

4. Absolute Weight

According to Efendi (1987), absolute weight growth can be calculated using the following formula:

$$Bm = Wt - Wo$$

Description: Bm = organism weight growth (g); Wt = organism biomass weight at the end of rearing (g); W0 = organism biomass weight at the beginning of rearing (g).

5. Absolute Length

According to Efendi (1987), absolute length increment can be calculated using the following formula:

$$Pm = Lt - Lo$$

Pm = absolute length increment (cm); Lt = final average length (cm); L0 = initial average length (cm).

6. Specific Growth Rate (SGR)

According to Efendi (1987), specific growth rate can be calculated using the following formula:

$$SGR = \text{Ln}\ Wt - \text{Ln}\ Wo\ /\ t \times 100\%$$

SGR = specific growth rate (%/day); Wt = organism biomass weight at the end of rearing (g); W0 = organism biomass weight at the beginning of rearing (g); t = rearing duration (days).

7. Survival Rate (SR)

Survival rate (SR) was observed to determine the percentage of Nile tilapia that survived during the study. According to Shofura et al. (2019), SR was calculated using the formula:

$$SR = Nt\ /\ No \times 100$$

Where: SR = survival rate of milkfish (%); Nt = number of milkfish at the end of rearing; N0 = number of milkfish at the beginning of rearing

8. Heterosis Value

Calculation of heterosis values included TFC, FCR, FUE, absolute weight, absolute length, SGR, and SR. The calculation was performed to determine the performance of hybrid fish compared with inbred fish. Heterosis was calculated using the formula used by Fahmi et al. (2021) and Wahyudi et al. (2022) as follows

$$H = (F - MP/2) :\ MP/2 \times 100\%$$

H = heterosis value (%); F1 = hybrid seed data; MP = average value of Kekar and Kunti seed.

Water Quality

Water quality observed in this study consisted of temperature, pH, DO, and salinity. Water temperature (°C) was measured using a thermometer. Water pH was measured using a pH meter. DO (mg/L) was measured using a DO meter. Salinity (ppt) was measured using a refractometer.

Data Analysis

Data analysis in this study was conducted statistically. Growth data including absolute weight, Specific Growth Rate (SGR), Relative Growth Rate (RGR), and survival rate (SR) were analyzed using analysis of variance (One-Way ANOVA) to determine the effect of four types of Nile tilapia seed crosses in saline media. Before ANOVA, data were tested for normality using the Shapiro–Wilk test and homogeneity of variance using Levene's test. If the ANOVA results showed a significant difference ($p < 0.05$), the analysis was continued with Duncan's multiple range test to determine differences among treatments. Water quality data analyzed by description methode.

RESULTS AND DISCUSSION

Results

Total Feed Consumpsion

The results of total feed consumption during the rearing period are presented in the Figure 1

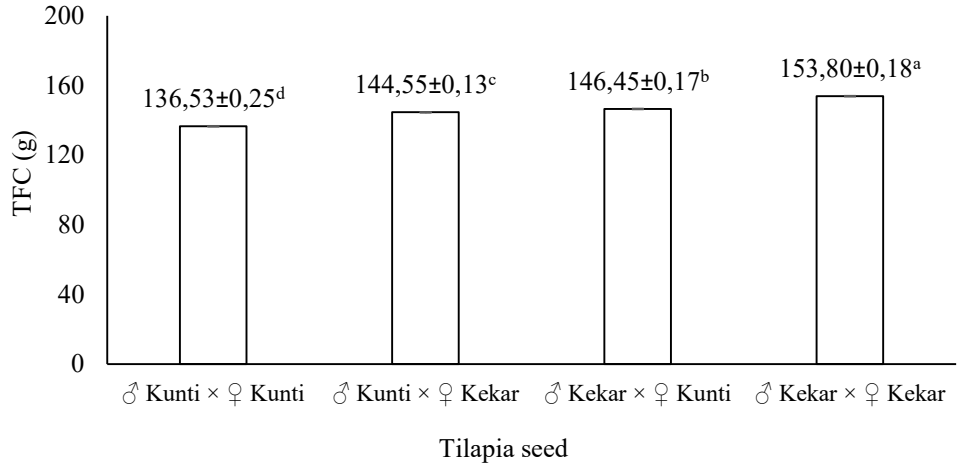

Figure 1. Total Feed Consumpsion

Tilaphia seeds Kekar, kunti and hybrid reared medium with salinity 15 ppt gave significant effect on TFC (P<0,5) . The highest TFC on P4, seed from ♂ Kekar × ♀ Kekar (153,80±0,18 g).

Food Conversion Ratio **(FCR)**

The feed conversion ratio (FCR) results during the rearing period are presented in Figure 2.

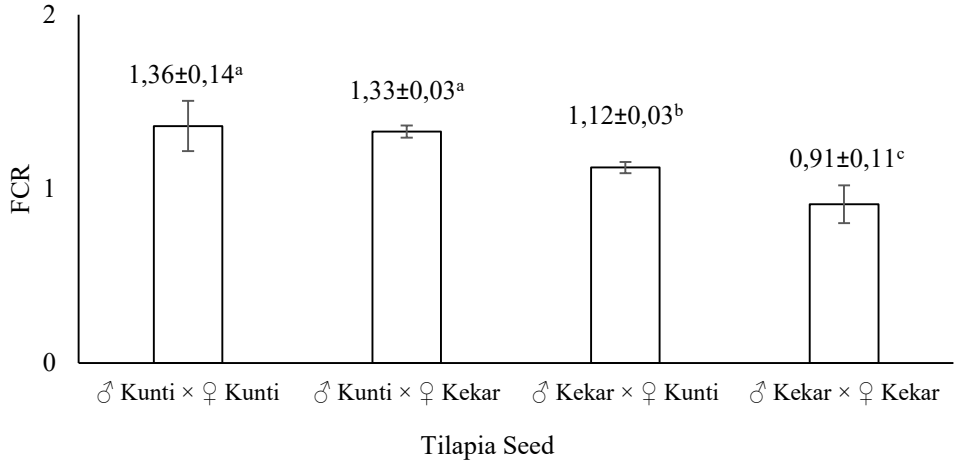

Figure 2. Feed Conversion Ratio

Tilaphia seeds Kekar, kunti and hybrid reared medium with salinity 15 ppt gave significant effect on FCR (P<0,5) . The lowest on P4, seed from ♂ Kekar × ♀ Kekar (0,91±0,11).

Feed Utilization Efficiency (FUE)

FUE results during the rearing period are presented in Figure 3.

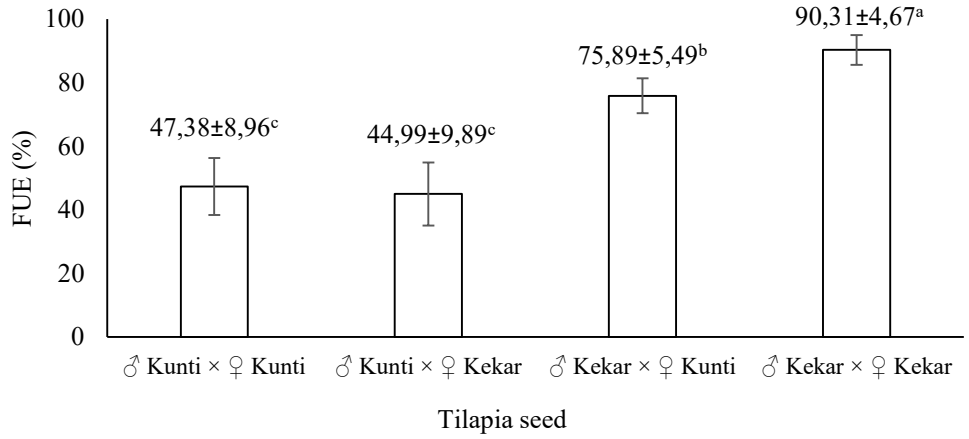

Figure 3. Feed Utilization Efficiency (FUE)

Tilaphia seeds Kekar, kunti and hybrid reared medium with salinity 15 ppt gave significant effect on FCR (P<0,5) . The lowest on P4, seed from ♂ Kekar × ♀ Kekar (90,31±4,67%).

Absolute Weight

The absolute weight results during the rearing period are presented in the histogram in Figure 4 .

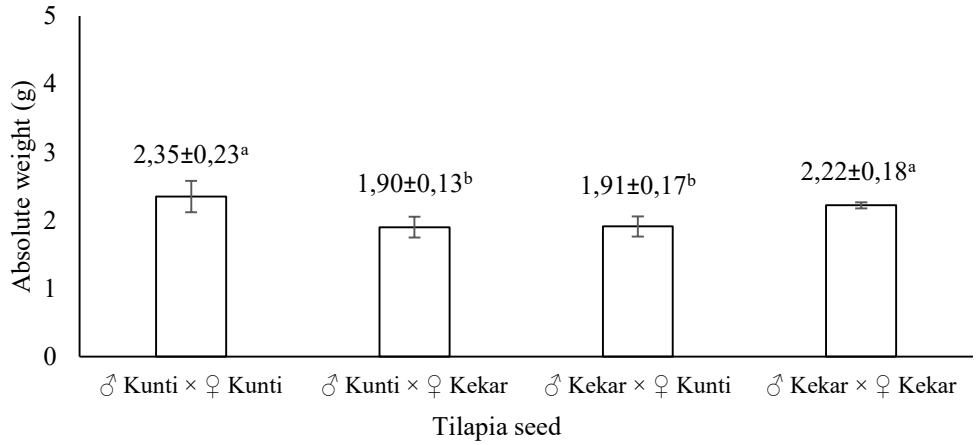

Figure 4. Absolute weight growth

Tilaphia seeds Kekar, kunti and hybrid reared medium with salinity 15 ppt gave significant effect on absolute weight growth (P<0,5). Seed absolute weigth growth of ♂ kunti × ♀ kunti and ♂Kekar × ♀ Kekar produced the same value and better than ♂ kunti × ♀ kekar and ♂Kekar × ♀ Kunti.

Absolute Length

The absolute length growth results during the rearing period are presented in the Figure 5.

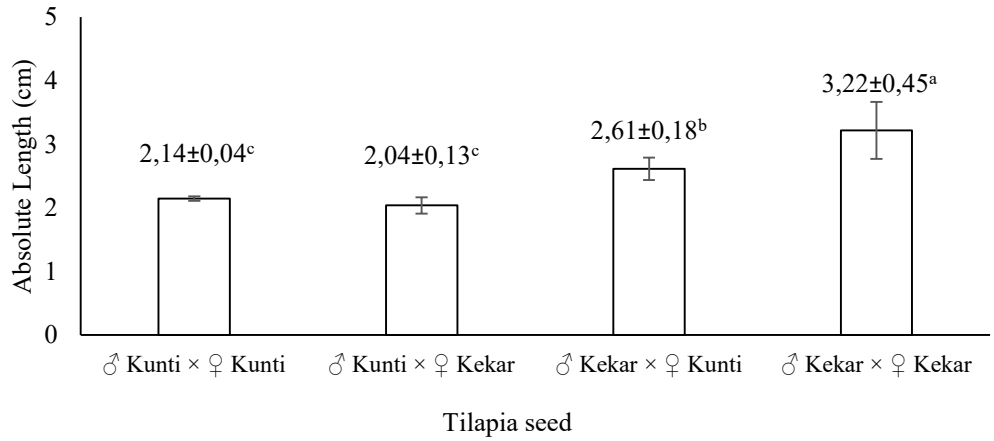

Figure 5. Absolute length growth

Tilaphia seeds Kekar, kunti and hybrid reared medium with salinity 15 ppt gave significant effect on absolute length growth (P<0,5). The best absolute lenght growth of seed ♂Kekar × ♀ Kekar (3,22±0,45) cm.

Specific Growth Rate **(SGR)**

The specific growth rate (SGR) results during the rearing period are presented in the Figure 6.

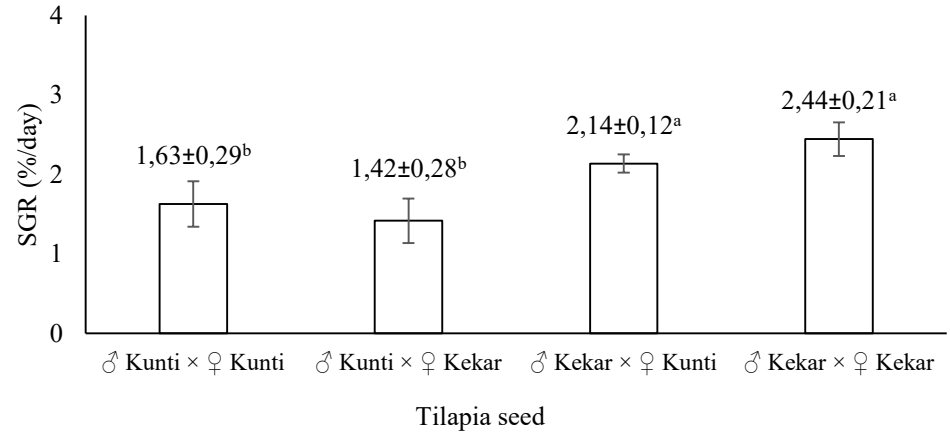

Figure 6. ***Specific Growth Rate***

Tilapia seeds of Kekar, kunti and hybrid had a highly significant effect on specific growth rate. Seed specific growth rate of ♂ kekar × ♀ kunti and ♂Kekar × ♀ Kekar produced the same value and better than ♂ kunti × ♀ kunti and ♂kunti × ♀ kekar.

Survival Rate **(SR)**

The survival rate results during the rearing period are presented in the Figure 7.

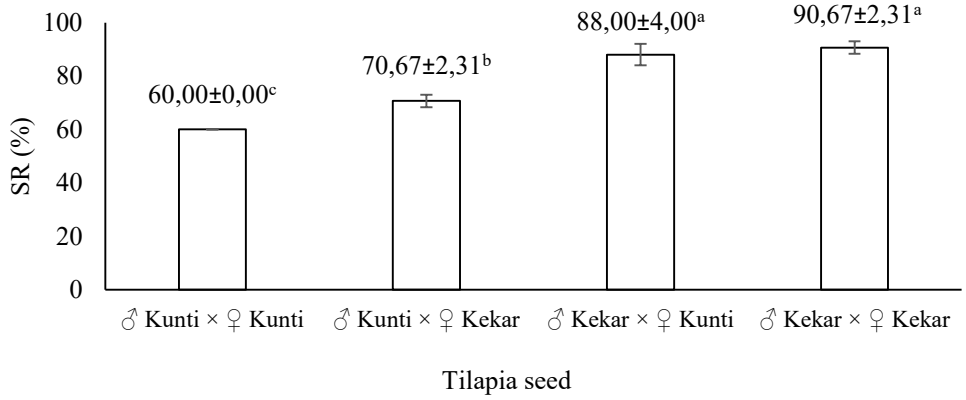

Figure 7. Survival Rate

Tilapia seeds of Kekar, kunti and hybrid had a highly significant effect on specific growth rate. Seed specific growth rate of ♂ kekar × ♀ kunti and ♂Kekar × ♀ Kekar produced the same value and better than ♂ kunti × ♀ kunti and ♂kunti × ♀ kekar

Heterosis

The results of heterosis value calculations are presented in Table 1

Table 1 Heterosis value of seed tilapia

Parameter	Heterosis Value(%)	
	P2 (♂ Kunti × ♀ Kekar)	P3 (♂ Kekar × ♀ Kunti)
Total Feed Consumpsion	-0,42	0,89
Feed Conversion Ratio	17,00	-1,18
Feed Utilizasion Efisiency	-34,64	10,23
Absolute Weigth	-16,78	-16,30
Absolute Length	-23,93	-2,51
Specific Growth Rate	-65,19	-47,52
Survival Rate	-6,19	16,81

Based on the heterosis value calculation (Table X), treatment P3 (♂ Kekar × ♀ Kunti) showed better heterosis values than treatment P2 (♂ Kunti × ♀ Kekar) for most observed parameters. Treatment P3 produced positive heterosis values for total feed consumption of 0.89%, feed utilization efficiency of 10.23%, and survival rate of 16.81%. In addition, although the heterosis values for feed conversion ratio (-1.18%), absolute weight (-16.30%), absolute length (-2.51%), and specific growth rate (-47.52%) were still negative, their values were better than those of P2. Meanwhile, treatment P2 showed a positive heterosis value only for feed conversion ratio (17.00%), whereas the other parameters showed negative heterosis values. These results indicate that crossing Kekar males with Kunti females (P3) has better heterosis potential than its reciprocal cross.

Water Quality

Water quality measurements were conducted twice a day throughout the study. The parameters measured included salinity, pH, temperature, and dissolved oxygen (DO). Salinity was measured using a refractometer. pH was measured using pH paper with a scale, while temperature and DO were measured using a DO meter. The water-quality measurement results are presented in Table 2.

Tabel 2. Water quality

Parameters	value	standart
Temperatur (°C)	26 – 29	25 – 30 (Syahputra *et al*., 2023)
pH	6,5 – 8,5	6,5 – 8,5 (Syahputra *et al*., 2023)
DO (mg/L)	4,01 – 6,49	>3 (Syahputra *et al*., 2023)
Salinity (ppt)	0 – 15,5	0 – 30 (Prayudi *et al*., 2017)

Based on the water-quality observations in Table 2, all water-quality parameters consisting of temperature, pH, DO, and salinity were within optimal values when compared with the suitable values for each parameter.

Discussion

Total feed consumption in Kekar Nile tilapia, Kunti Nile tilapia, and their crosses reared in 15 ppt saline media produced different results. These results indicate that different genetic sources of the parents affected total feed consumption in Nile tilapia seed. Kekar Nile tilapia seed showed the highest total feed consumption (153.80±0.18 g) compared with Kunti Nile tilapia seed or their crosses. Meanwhile, seed resulting from the ♂ Kekar × ♀ Kunti cross had higher TFC than ♂ Kunti × ♀ Kekar seed. The high feed consumption in treatments dominated by Kekar Nile tilapia genetics was presumably related to parental characteristics having higher metabolic rates, energy requirements, and appetite than Kunti Nile tilapia (Prayuda et al., 2017; Pramleonita et al., 2018). In addition to genetic factors, rearing in 15 ppt saline media also increases energy

requirements for osmoregulation, thereby encouraging fish to consume more feed as a physiological adaptation to environmental stress (Fradina and Latuconsina, 2022; Gaitian et al., 2024). Conversely, Kunti Nile tilapia tends to have a more efficient energy-utilization strategy, resulting in relatively lower feed consumption (Gustiano et al., 2008; Hendriana et al., 2023)

Food Conversion Ratio during rearing of Kekar Nile tilapia, Kunti Nile tilapia, and their crosses ranged from 0.91±0.11 to 1.36±0.14. The use of different parental strains affected FCR in the seed, with the best result observed in 7 seed from Kekar Nile tilapia spawning. The genetic source of Kekar Nile tilapia was presumably associated with better feed efficiency, so that consumed feed could be utilized by the fish for optimal growth. Differences in FCR among treatments reflect variation in genetic ability to digest and utilize feed, where the combination of rapid growth characteristics of Kekar Nile tilapia and nutrient absorption efficiency of Kunti Nile tilapia also influenced the resulting feed efficiency (Widiastuti et al., 2020; Tahapari and Darmawan, 2018; Setiawati et al., 2017) .

Feed utilization efficiency (FUE) also showed a similar pattern in describing the fish's ability to utilize consumed nutrients. The highest FUE value was observed in the ♂ Kekar × ♀ Kekar treatment, indicating the best ability to convert feed into body biomass, where the higher the FUE value, the more efficient the feed utilization by the fish (Faisal et al., 2017). High feed utilization efficiency ultimately contributes to fish growth, one indicator of which is absolute weight gain. In saline media, some energy is presumably allocated more to osmoregulation and maintenance of homeostasis than to biomass formation, resulting in lower weight growth in the crossbred groups compared with pure strains (Wahyudi et al., 2022; Pratama et al., 2021; Sari et al., 2019).

In addition to increasing body weight, successful nutrient utilization is also reflected in absolute length growth as an indicator of fish skeletal development. Absolute length growth showed the highest value in the ♂ Kekar × ♀ Kekar treatment at 3.22±0.45 cm, whereas the lowest values were obtained in the ♂ Kunti × ♀ Kunti and ♂ Kunti × ♀ Kekar treatments, at 2.14±0.04 cm and 2.04±0.13 cm, respectively. These results indicate that the Kekar strain has better skeletal growth ability in 15 ppt saline media, presumably due to more optimal ion regulation and osteogenesis processes, so that bone growth is not disrupted by osmotic stress (Niode *et al*., 2017; Li *et al*., 2025). Conversely, the low length growth in treatments dominated by Kunti genetics was presumably caused by high energy allocation to osmoregulation, thereby inhibiting growth hormone synthesis and bone tissue formation (Qiang *et al*., 2017; De Oliveira *et al*., 2022). These differences indicate that the genetic characteristics of each strain play an important role in determining fish length growth in saline environments (Supriyadi *et al*., 2020; Rahmawati *et al*., 2021)

Survival rate (SR) showed that crossing Kunti and Kekar Nile tilapia produced different responses in adaptation ability to 15 ppt saline media. The highest SR value was obtained in the ♂ Kekar × ♀ Kekar treatment at 90.67±2.31%, followed by ♂ Kekar × ♀ Kunti at 88.00±4.00%, while the lowest value occurred in ♂ Kunti × ♀ Kunti at 60.00±0.00%. The high SR in treatments involving Kekar males was presumably associated with better osmoregulatory ability, allowing fish to maintain ion balance and reduce salinity-induced stress, whereas the low SR in the pure Kunti treatment indicates lower physiological adaptation ability to osmotic stress (Azevedo *et al*., 2015; El-Leithy *et al*., 2019; Ni *et al*., 2021). These results indicate that differences in genetic background affect the success of fish adaptation during rearing, where genetic combinations more tolerant to salinity can increase fish survival (Gustiano *et al*., 2018; Fahmi., 2022).

Heterosis values showed that reciprocal crosses produced different genetic responses for each parameter. Treatment ♂ Kunti × ♀ Kekar (P2) was dominated by negative heterosis values, particularly for specific growth rate (SGR), as well as a positive FCR heterosis value, indicating lower growth performance and feed efficiency compared with the parental mean. Conversely, treatment ♂ Kekar × ♀ Kunti (P3) showed better heterosis, characterized by increased survival rate (16.81%), feed utilization efficiency (10.23%), and a negative FCR heterosis value (-1.18%), indicating more efficient feed utilization. These results indicate that the combination of Kekar males and Kunti females has better genetic compatibility than its reciprocal cross and has the potential to produce seed that is more adaptive to saline media (Bentsen et al., 2017; Rostika et al., 2020; Fahmi et al., 2021; Iskandar et al., 2022)

CONCLUSION

Based on the research results, crossing Kekar and Kunti Nile tilapia seed affected the growth performance and survival of seed reared in 15 ppt saline media. The best treatment was the ♂ Kekar × ♀ Kekar cross, which produced total feed consumption of 153.80±0.18 g, feed conversion ratio of 0.91±0.11, feed utilization efficiency of 90.31±4.67%, absolute weight of 2.22±0.18 g, absolute length of 3.22±0.45 cm, specific growth rate of 2.44±0.21%/day, and survival rate of 90.67±2.31%. These results indicate that the Kekar

Nile tilapia strain had better performance than the other cross combinations in supporting growth, feed utilization efficiency, and adaptation ability in saline media.

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