



Effect of 17 α -methyl testosterone on sex reversal and growth performance of Nile tilapia, *Oreochromis niloticus*

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KEYWORDS:

Sex-reversal;
Methyl testosterone;
Mono-sex production;
Hapa;
Nile tilapia

ABSTRACT

The present study aimed at developing all-male Nile tilapia using 17 α -methyl testosterone (17 α -MT) along with its growth and feed utilization performances. Three days old Nile tilapia fry were stocked in plastic jars with 5 L capacity installed in four fiber glass tanks. The fry were fed with 0, 30, 60, and 100 mg MT/kg diets for 30 days. Later, the fry were shifted to hapas installed in a pond and then, reared for four months separately. The fish were fed with the control diet. The results showed that the highest male population (93.6%) was observed in the fish treated with a 60 mg MT/kg diet, while the lowest (82.6%) was observed in the fish treated with a 30 mg MT/kg diet. The results also showed that the fish fed with a 60 mg MT/kg diet had significantly higher mean body weight (24.1 \pm 1.40 g), specific growth rate (2.5 \pm 0.10%), feed conversion ratio (1.3 \pm 0.10), and protein efficiency ratio (0.63 \pm 0.11) than the untreated fish treated (control) group. In conclusion, a 60 mg MT/kg diet can be considered as an optimal and economically viable dose for Nile tilapia sex reversal along with its optimum growth and feed utilization performances.

INTRODUCTION

Among several cultivable fish species, tilapia has been identified as the second most important aquaculture fish species in the world, particularly in the tropical and sub-tropical countries next to carp (El-Sayed, 2006; Dagne *et al.*, 2013). It is also considered as one of the most important traded fish in the world (Kyule *et al.*, 2014; Magbanua and Ragaza, 2022). Farmed tilapia production increased significantly from 383,654 tons in the 1990s to

4,514,615 tons of production in 2020 (FAO, 2022). Basically, for optimal production performance of the semi-intensive fish culture, high quality fish feed are the most preferred due to their good palatability and digestibility required for body maintenance, growth, reproduction and health (Howlader *et al.*, 2023).

Although Nile tilapia has such good characteristics, its precocious and prolific reproduction and early sexual maturation of female has become one of the main challenges

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for considering this species for commercial aquaculture (Chakraborty and Benerjee, 2012; Munguti *et al.*, 2014). This resulted in the reduction of growth rate at the onset of sexual maturation and the production of a large number of fry/fingerlings (Munguti *et al.*, 2014). Considering the differential growth patterns of males and females, all-male Nile tilapia production has been given better consideration as males are capable of showing a better growth rate and food conversion efficiency (Chakraborty and Banerjee, 2012). It is in this context, production of all-male populations of Nile tilapia is vital for increasing fish production under low management practices (El-Sayed, 2006). Among the various techniques employed, hormonal sex-reversal has been considered as an effective method (Ferdous and Ali, 2011; Jamila *et al.*, 2017). Even though it is the most important method, reports of different authors are not consistent (Wahby and Shalaby, 2010; Celik *et al.*, 2011; Lakshmi, 2015). Celik *et al.* (2011) reported that the efficiency of such a method can be affected by different environments, feeding rates, and feeding management, and overall production management. Hence, the evaluation of such method in a specific production environment is crucial. Thus, the main objective of this study was to find out an optimum dose of 17 α -methyl testosterone on the proportion of Nile tilapia male population along with growth performance and feed utilization efficiency of Nile tilapia under a semi-intensive production system.

MATERIALS AND METHODS

Experimental setup

The experiment was carried out at Ziway Fishery and Other Aquatic Life Research

Centre, Ziway. The research Centre is situated at 163 km Southeast direction of Addis Ababa, the capital city of Ethiopia. It is located at 7°52' to 8°8' N latitude and 38°40' to 38°56' E longitude, at an altitude of 1636 m above sea level. For this study, indoor and outdoor experimental setups were used. For the indoor experiment, four fibre glass tanks each with a size of 2000 ML were prepared. Within each tank, three plastic circular shape jars with 5 L capacity were installed for hormone-treated feed trial experiments. For the outdoor experiment, 12 hapas with 1.5 m x 2 m x 1 m size were installed in a concrete pond. Before installation of the hapas, the pond was dried for one week and then, refilled with water at depth of 90 cm.

Source of experimental fish and feed formulation

Sexually matured Nile tilapia broodstock that measured 200 to 250 g body weight were selected from the holding tank of the Ziway research centre and immediately transferred into hapas with 1.5 m x 2 m x 1 m size installed in a pond at a stocking density of 4 fish/hapas with a sex ratio of 1 male to 3 females for mating (ref.). From these hapas, newly hatched Nile tilapia fry were collected and transferred in plastic bottles having 5 L water holding capacity for feed trial experiments. The experiment was conducted in triplicates with four treatments (i.e., 0, 30, 60, and 100 mg MT/kg of diets).

Fish diet was formulated by mixing 43% of fishmeal, 36% of Niger cake, 10% of wheat bran, 7% of white corn flour, 2% of vitamins and mineral premix, and 2% of sunflower oil, having 38% of crude protein. Later, the mixed ingredients was divided into four groups, in which the first one was not treated with 17 α -

methyl testosterone (0 mg MT/kg of diets) was used as a control diet, while the remaining three groups were treated with 30, 60 and 100 mg MT dissolved in 95% ethanol per kilogram diet and were used as tested diets. The control diet was also mixed with the same amount of ethanol without hormone. Then, the diets were dried at room temperature for 24 hours and were stored in a refrigerator (Celik *et al.*, 2011).

Indoor and outdoor experiments

Immediately after hatching, 300 newly hatched fry collected from the hapas were transferred into 12 plastic bottles installed in 4 fiberglass rearing tanks for three days of acclimatization. Later, after hatching 240 fry, 20 fry per plastic bottle, with an average body weight of 0.05 g were distributed in 12 plastic bottles having 5 L water holding capacity installed in four fiberglass rearing tanks in triplicates and reared for one month. To facilitate water circulation, the bottles were provided with small holes which were less than the size of the fry. The fry were, then, fed four times at 8:00, 12:00 and 16:00 and 18:00 hours a day with 0 mg MT, 30 mg MT, 60 mg MT and 100 mg MT/kg diets having 38% crude protein for 30 days at 20% of their body weight (Shamsuddin *et al.* (2012). Early morning, uneaten food and faecal matter were removed daily using siphoning. Oxygen was provided to each tank using aerators. After 30 days of treatment, total body weight of the all fry were measured and then transferred and stocked in hapas with a size of 1.5 m x 2 m x 1 m installed in the grow-out pond at an average stocking density of 18 fish per hapa and reared for four months. During this time, the fish were fed three times at 9:00, 13:00 and 17:00 hours a day with a control diet at 10% of their body weight (Mugo-Bundi (2013). The overall

research procedure was approved by the research committee of Hawassa University and thus, all applicable international and national guidelines for the care of animals and use of animals were followed by the authors.

Data collection and sex determination

Every 15 days (2 weeks) of interval, individual body weight and body length of hormone-treated fish stocked in plastic bottles were recorded early morning. The mortality of the fry was recorded daily. Similarly, every 15 days of interval, individual body weight and body length of the experimental fish stocked in hapa were recorded. At the end of the experiment (on week 16, i.e. harvesting week), the final body weight and body length of all the fish were recorded. In addition, the sex of each fish was identified based on external and internal observation of the sex organs of the fish. Iodion solution as dye was used to differentiating the sex of the fish when the secondary sexual characters were found difficult to differentiate. Ten fish per treatment were dissected and the morphology of the gonads was examined and recorded. Water quality parameters such as water temperature, pH, dissolved oxygen, conductivity, and total dissolved solid were measured using Potable Multi-Parameter Kit.

Following final body weight and length measurements, calculation of growth parameters were performed using the following formula described by Eyo *et al.* (2013).

- I. Calculation of growth and feed utilization efficiency:
 - Body weight gain (BWG) = Final body weight (FBW) – Initial body weight (IBW)

- Daily growth rate (DGR) = Weight gain/Number of experimental days
- Specific growth rate (SGR % per day) = $((\text{LnFBW} - \text{LnIBW}) / \text{Number of days}) * 100$

II. Calculation of feed utilization efficiency:

- ✓ Food conversion ratio (FCR) = Amount of dry food intake/Weight gain
- ✓ Protein efficiency ratio (PER) = Weight gain/amount of crude protein

III. Calculation of survival rate, condition factors and fish yield (put Ref. for each formula):

- ✓ Survival rate (SR%) = Number of harvested fish/Number of stocked fish *100
- ✓ Condition factor (CF) = Final body weight/(Length³) x 100
- ✓ Total production = (No. of fish harvested × FBW/Area of rearing place) x10000 m² x production cycle

Statistical analysis

Based on the data recorded and calculated values basic statistics were computed using SPSS 20 version after the data were tested for normality and equal variance. The statistical significance among growth parameters and sex ratio of fish fed with different test diets were computed using one-way ANOVA (Analysis of

Variance) in the SPSS. Significance was assigned at a 5% level of probability. For between mean treatments significant variation, was performed using Tukey HSD standardized range test = 0.05 level of significance as described according to El Greisy and El-Gamal (2012).

RESULTS

Indoor growth and survival rate of Fry

The mean body length and weight of fry at stocking and after 30 days of hormone treatment of all groups are presented in Table 1. The initial mean body length and body weight of fry were the same (1.3 cm and 0.05 g). After one month of rearing, the length of fry ranged from 3.3±0.12 cm (30 mg MT/kg diet) to 3.7±0.30 cm (60 mg MT/kg diet) while the mean body weight of the fry ranged from 0.81±0.18 g (60 mg MT/kg diet) to 0.84±0.13 g (control diet). Additionally, the survival rate of the fish in different treatments was high, ranging from 88.2±2.1 to 92.2±1.6%. In all cases, there was no significant ($P > 0.05$) difference in survival rates among the treatments (Table 1).

Table 1: Mean body size parameters with standard error (Mean + SE) of fry at stoking and after 30 days of oral administration with different doses of 17 -methyl testosterone (17 -MT).

Parameters	Treatments			
	0 mg MT/kg diet	30 mg MT/kg diet	60 mg MT/kg diet	100 mg MT/kg diet
Initial body length (cm)	1.3±0.37	1.3±0.37	1.3±0.37	1.3±0.37
Initial body length (g)	0.05±0.02	0.05±0.02	0.05±0.02	0.05±0.02
Body length (cm) after 30 days of treatment	3.4±0.20 ^a	3.3±0.12 ^a	3.7±0.30 ^a	3.4±0.20 ^a
Body weight (g) after 30 days of treatment	0.84±0.13 ^a	0.82±0.20 ^a	0.81±0.18 ^a	0.82±0.15 ^a
Survival rate (SR%)	90.2±1.4 ^a	90.2±1.2 ^a	92.2±1.6 ^a	88.2±2.1 ^a

Note: Values with the same letter across a row are not significantly different ($P > 0.05$)

Effects of MT on sex ration

The sex ratio of Nile tilapia fed with hormone-treated diets is presented in Table 2. The gonad differentiation of fish fed with the MT-treated diets gave a higher male proportion than fish fed with the control diet. The maximum male population (93.6%) was observed for the fish fed with a 60 mg MT/kg diet followed by a 100

mg MT/kg diet (86.7%), while the lowest male population was observed for the fish fed with the control diet (54.3%). The results showed that the fish fed with a 60 mg MT/kg diet produced significantly ($P < 0.05$) higher male population than the other groups while the fish fed with the control diet produced the least significant.

Table 2: Percentage of male population of Nile tilapia produced after oral administration with different doses of 17 α -methyl testosterone (17 α -MT).

Dose of MT	Male %	P value
0 mg MT/kg (control) diet	54.3 ^a	0.35
30 mg MT/kg diet	82.6 ^b	< 0.001
60 mg MT/kg diet	93.6 ^c	< 0.001
100 mg MT/kg diet	86.7 ^b	0.005

Note: Values with the same letter across column are not significantly different ($P > 0.05$)

Outdoor growth performance

The different growth parameters such as mean body weight gain, daily growth rate, and specific growth rate, and feed utilization efficiency such as feed conversion ratio and protein efficiency ratio of Nile tilapia fed with different doses of MT-treated diets are presented in Table 3. The results showed that the highest mean body weight (24.1 ± 1.4 g) and body weight gain (24.0 ± 1.2 g) were recorded in the fish fed with 60 mg MT/kg diet followed by 100 mg MT/kg diet (19.1 ± 0.8 g and 19.0 ± 0.2 g), while the lowest (14.3 ± 1.8 g) and 14.2 ± 0.1 g) was observed for the fish fed with a control diet, respectively. Similarly, the highest mean body

length (11.1 ± 1.2 cm) was observed for the fish fed with 60 mg MT/kg diet, followed by 10.2 ± 1.2 cm mean body length of fish fed with 100 mg MT/kg diet, while the lowest (9.1 ± 0.79 cm) was observed for the fish fed with control diet (Table 3). The results also showed that the fish fed with hormone treated diets had significantly ($P < 0.05$) higher final mean body weight, in which the fish fed with 60 mg MT/kg diet had significantly ($P < 0.05$) higher final mean body weight, and mean weight gain than at least from the fish fed with the control diet. Figure 1 also showed the growth trend of body weight of the fish, in which fish body weight increased steadily for the first six weeks, and then, the rate of growth slightly increased.

Table 3: Mean growth parameters with standard error (Mean + SE) of Nile tilapia treated with different doses of 17 -methyl testosterone (17 -MT).

Parameters	Treatments			
	0 mg MT/kg diet	30 mg MT/kg diet	60 mg MT/kg diet	100 mg MT/kg diet
Initial body length (cm/fish)	1.3±0.37 ^a	1.3±0.37 ^a	1.3±0.37 ^a	1.3±0.37 ^a
Initial body weight (g/fish)	0.05±0.02 ^a	0.05±0.02 ^a	0.05±0.02 ^a	0.05±0.02 ^a
Final body length (cm/fish)	9.1±0.79 ^a	9.6±1.03 ^a	11.1±1.19 ^a	10.2±1.17 ^a
Final body weight (g/fish)	14.3±1.84 ^a	18.3±2.46 ^b	24.1±1.38 ^b	19.1 ±0.79 ^b
Body weight gain (g/fish)	14.2±0.02 ^a	18.2±0.02 ^b	24.0±0.21 ^c	19.0±0.21 ^b
Daily growth rate (g/fish/day)	0.12±0.01 ^a	0.15±0.01 ^{ab}	0.20±0.1 ^b	0.18±0.01 ^{ab}
Specific growth rate (%/fish/day)	2.2±0.2 ^a	2.3±0.01 ^{ab}	2.5±0.1 ^b	2.4±0.1 ^{ab}

Note: Values with the same letter across rows are not significantly different ($P > 0.05$)

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weight, and mean weight gain than at least from the fish fed with the control diet. Figure 1 also showed the growth trend of body weight of the fish, in which fish body weight increased steadily for the first six weeks, and then, the rate of growth slightly increased.

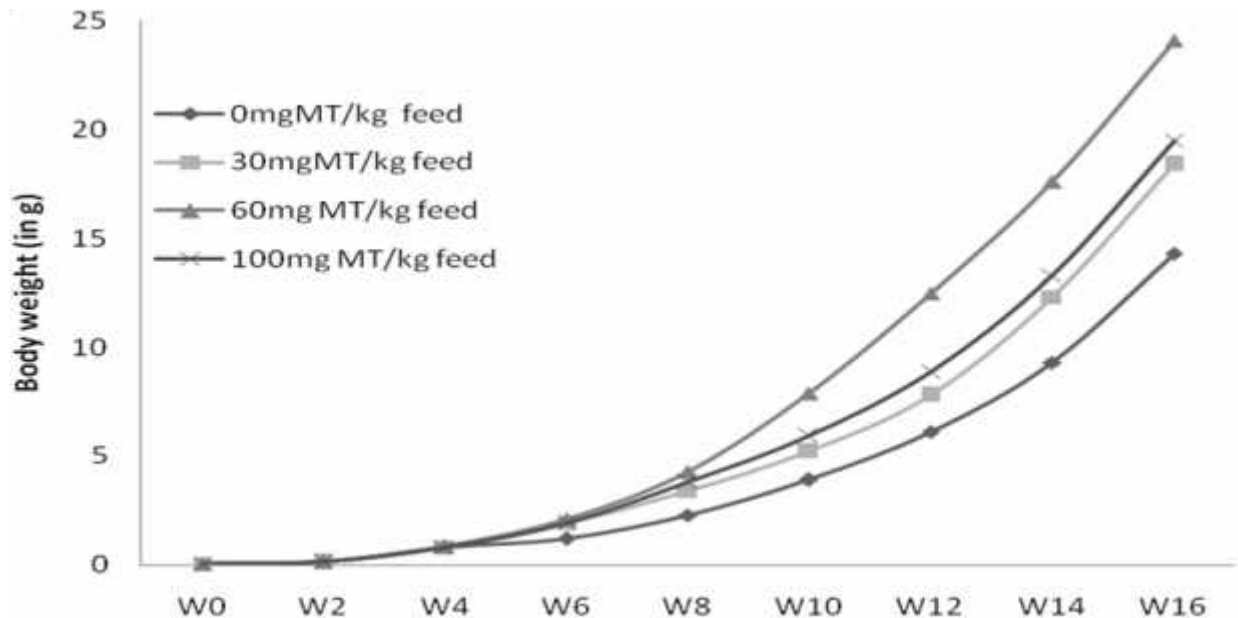


Figure 1: The trend of mean weight of different group of Nile tilapia reared in hapa installed in pond, where W0 to W16 are rearing times in weeks at two weeks interval, W0 is for initial week, i.e. week zero, while W16- week sixteen, i.e. harvesting week

Similarly, the results revealed that the highest mean daily growth rate (0.20 ± 0.1 g/day) and specific growth rate ($2.5 \pm 0.01\%$ /day) were recorded for the fish fed with 60 mg MT/kg treated diet than the other groups of fish fed with different level of MT. They were

significantly different ($P < 0.05$) at least from the lowest mean daily growth rate (0.12 ± 0.01 g/day) and specific growth rate ($2.2 \pm 0.02\%$ /day) of the fish fed with the control diet. The trend of daily growth rate and specific growth rate fluctuated as the rearing period increased (Figures 2 and 3).

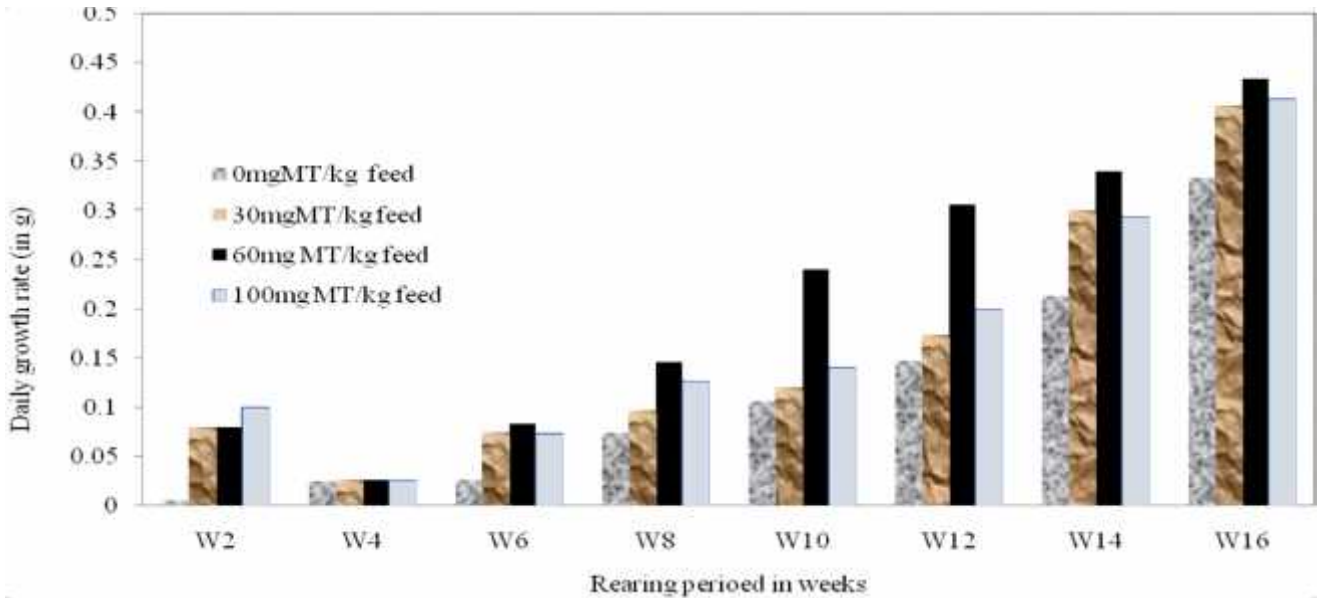


Figure 2: The trend of daily growth rate of different group of Nile tilapia reared in hapa installed in pond

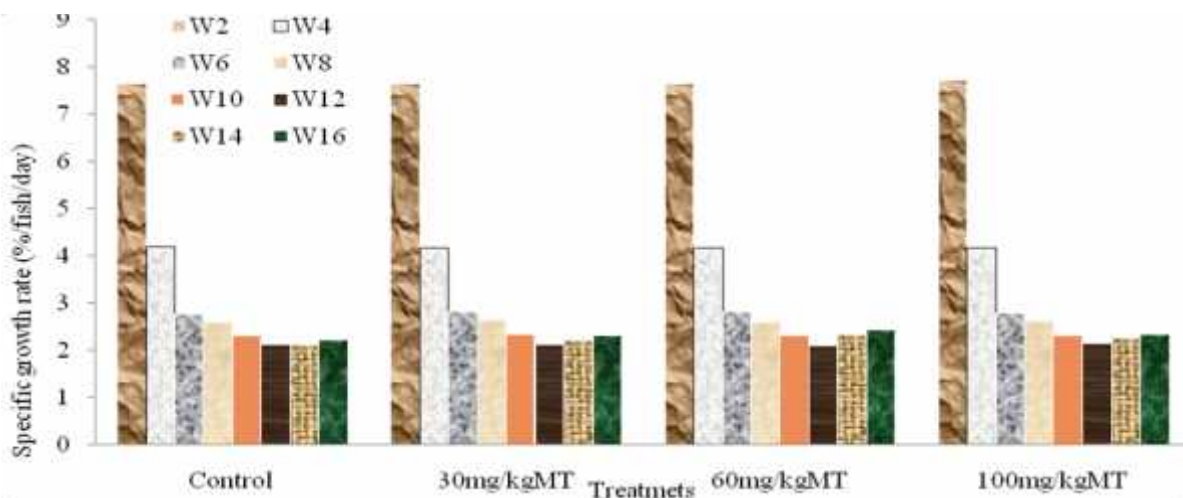


Figure 3: The trend of specific growth rate of different group of Nile tilapia reared in hapa installed in pond, where W2 to W16 are rearing times in weeks, in which fish sampling was taken at two weeks interval, W2 was the first sampling times in which fish were sampled after two weeks rearing, while W16- week sixteen, i.e. harvesting week.

Feed utilization efficiency and condition factor and weight-length relationship

The mean values of feed utilization efficiency parameters and condition factors of Nile tilapia fed with a control diet and MT-treated diets are presented in Table 4. The food conversion ratio (FCR) of different fish fed with different levels of MT ranged from 1.3 ± 0.1 to 2.3 ± 0.1 , while from 0.37 ± 0.1 to 0.63 ± 0.11 for protein efficiency ratio (PER). The best FCR and PER were obtained for the fish fed with a 60 mg MT/kg diet and were significantly ($P < 0.05$)

different at least from the fish fed with the control diet.

The condition factor of Nile tilapia fed with control, 30 mg MT, 60 mg MT and 100 mg MT/kg diets were similar and ranged from 1.8 ± 0.12 to 2.1 ± 0.17 . According to cube law, the 'b' values for all groups of fish are in a good condition. The 'b' values ranged from 2.8 ± 0.16 to 2.9 ± 0.14 . The results showed that both Fulton condition factor and weight-length relationship parameters were no significant differences among groups (Table 4).

Table 4: Mean feed utilization efficiency, condition factor, survival and total production with standard error (Mean + SE) of Nile tilapia treated with different doses of 17 -methyl testosterone (17 -MT)

Parameters	Treatments			
	0 mg MT/kg diet	30 mg MT/kg diet	60 mg MT/kg diet	100 mg MT/kg diet
Food conversion ratio	2.3 ± 0.1^a	1.8 ± 0.3^b	1.3 ± 0.12^b	1.8 ± 0.13^b
Protein efficiency ratio	0.37 ± 0.1^a	0.48 ± 0.12^a	0.63 ± 0.11^a	0.50 ± 0.20^a
Fulton condition factor	1.9 ± 0.13^a	2.1 ± 0.17^a	1.8 ± 0.14^a	1.8 ± 0.12^a
Weight-length relationship	2.8 ± 0.16^a	2.9 ± 0.21^a	2.9 ± 0.18^a	2.9 ± 0.14^a
Survival rate (SR%)	100 ± 0.00^a	100 ± 0.00^a	97.9 ± 0.12^a	100 ± 0.00^a
Total production (TP kg/ha/y)	2574.3 ± 52.1^a	3294.6 ± 42.6^b	4338.7 ± 73.2^c	3438.2 ± 63.6^b

Note: Values with the same letter across row are not significantly different ($P > 0.05$)

Survival rate of fish and fish production

The survival rate and total production of all the Nile tilapia groups are presented in Table 4. The survival rates of different Nile tilapia groups were similar, ranging from $97.9 \pm 1.2\%$ to $100 \pm 0.0\%$, while the total productions of different groups ranged between 2574.3 ± 52.1 kg/year/ha and 4338.7 ± 73.2 kg/year/ha. The fish fed with a 60 mg MT/kg diet had significantly higher total production at least from the fish-fed with the control diet. The results revealed that as the amount of MT dose increased from 60 mg

MT/kg to 100 mg MT/kg diet the total fish production decreased (Table 4).

Water quality parameters

The different water quality parameters (pH, temperature, dissolved oxygen, total dissolved solid and conductivity) recorded during the experimental periods for both indoor and outdoor experiments are presented in Table 5. The results of the indoor experiment showed that the different water parameters across treatments were similar. The values of temperature ranged from 24.0 ± 0.3 °C to 24.4 ± 0.5 °C, pH ranged from 7.6 ± 0.4 to 7.8 ± 0.6

and dissolved oxygen from 3.6 ± 0.3 mg/l to 3.8 ± 0.7 mg/l. The values of total dissolved solids and conductivity also ranged from 448.6 ± 3.4 mg/l to 451.1 ± 3.2 mg/l and from 592.4 ± 2.6 μ s/cm to 594.9 ± 2.7 μ s/cm, respectively. However, none of the water quality parameters were significantly different among the treatments. For outdoor experiments, the

results showed that the mean values of all water quality parameters recorded during the experimental period were optimal (28.5 ± 1.1 °C for temperature, 8.7 ± 2.0 for pH, 8.7 ± 1.3 mg/l for dissolved oxygen, 543.3 ± 3.5 mg/l for total dissolved solid and 721.4 ± 5.27 μ s/cm for conductivity).

Table 5: Mean values of different water quality parameters with standard error (Mean \pm SE) recorded during indoor and outdoor experiments.

Water quality parameters	Indoor experiment				Outdoor experiment
	Treatments				
	0 mg MT/kg diet	30 mg MT/kg diet	60 mg MT/kg diet	100 mg MT/kg diet	
Temperature (°C)	24.4 ± 0.5^a	24.3 ± 0.4^a	24.3 ± 0.4^a	24.0 ± 0.3^a	28.5 ± 1.1
pH	7.7 ± 0.3^a	7.7 ± 0.4^a	7.8 ± 0.6^a	7.6 ± 0.4^a	8.7 ± 2.0
Dissolved oxygen (mg/l)	3.6 ± 0.3^a	3.6 ± 0.8^a	3.8 ± 0.5^a	3.8 ± 0.7^a	8.7 ± 1.3
Total dissolved solid (mg/l)	450.7 ± 3.9^a	448.6 ± 4.7^a	451.1 ± 4.1^a	449.6 ± 5.2^a	543.3 ± 3.5
Conductivity (μ s/cm)	593.6 ± 3.4^a	594.9 ± 2.7^a	592.4 ± 2.6^a	593.9 ± 3.7^a	721.4 ± 5.2

Note: Values with the same letter across row are not significantly different ($P > 0.05$).

DISCUSSION AND CONCLUSIONS

This study demonstrates that the application of 17 methyl testosterone at 30, 60, and 100 mg per kg diets produced a higher male population and growth performance than fish fed with untreated diet. Among the hormone-treated diets, the fish fed with 60 mg MT/kg diet produced a significantly higher male population and body growth ($P < 0.05$) than the other groups. This result agreed well with the reports of El-Greisy and Gamal (2012) who reported a significantly higher male population using 60 mg MT/kg diet than 40 and 80 mg MT/kg diets. This result also coincides well with the results of Celik *et al.* (2011) and Shamsuddin *et al.* (2012) who reported 93.7% and 95% male population, using 60 mg MT/kg diet treated for 28 and 21 days, respectively. A similar result was reported by Ferdous and Ali (2011) who observed a maximum (94.3%) male population using a 60 mg MT/kg diet. These results are in line with the findings reported

by Marjani *et al.* (2009) in which higher growth performance of fish was obtained after hormone treatment.

The present results also showed a higher male population (93.6%) for 60 mg MT/kg diet than the report of Abdul (2007) (89%) and Asad *et al.* (2010) (68%) for the same MT doses. On the other hand, the results of the present study showed a relatively lower male population as compared with 99-100% for fish treated with 60 mg MT/kg diet (Vera-Cruz and Mair, 1994; Smith and Phelps, 2001). Such differences could be due to differences in management practices. As also indicated by Lakshmi (2015) and Sourav (2016) such differences in male population could be due to factors such as the level of hormone in the diet, feeding and feeding frequency, water quality parameters, treatment duration, size at which the fry is selected for experimentation and stocking density.

Different doses of MT resulted in the different growth rates of Nile tilapia in which fish group treated with a 60 mg MT/kg diet showed significantly higher mean body weight, body weight gain, daily growth rate, and specific growth rate of Nile tilapia than the other groups. This result is in agreement with the report of Pechsiri and Yakupitiyage (2005) and Opiyo *et al.* (2014), who observed optimal growth performance of fish when treated with 60 mg MT/kg diet. Also, the results of the present study showed that the fish treated with MT treated diets had significantly higher feed utilization efficiencies than fish treated with control diet. Statistically, the fish fed with a 60 mg MT/kg diet had the best feed utilization efficiency in terms of feed conversion ratio and protein efficiency ratio. This implies that 60 mg MT/kg diet promotes better growth performance, better feed utilization in fish as also reported by Mugo-Bundi (2013).

The significant growth performance and feed utilization efficiency of fish fed with MT/kg diets agreed well with the findings of Howerton *et al.* (1992) and Varadaraj *et al.* (1994) who reported a higher growth rate in *O. mossambicus* fed with MT treated diet than the fish fed untreated diet. The present results also indicated that the fish treated with 60 mg MT/kg diet for 30 days showed maximum growth performance and feed utilization efficiency than the other groups, and further increase or decrease of hormone dose do not have much influence on growth and feed utilization efficiency in fishes as it seems optimal dose. This result also coincides with the work of Lakshmi (2015) who reported faster growth and better feed utilization of Nile tilapia when treated with a 60 mg MT/kg diet. El-Greisy and El-Gamal (2012) also reported higher growth and feed utilization efficiency in fish treated with 60 mg MT/kg diet than 40 and 80 mg MT/kg diets. This implies that a 60 mg MT/kg diet is an optimum dose of MT hormone for optimal production of male population, better growth and feed utilization efficiency and can be considered as

an optimal dose for Nile tilapia sex-reversal under the current production management.

On the other hand, the condition factor of all groups of Nile tilapia were similar implying that condition factors were not influenced by MT doses. As stated by Ayode (2011), the fish from all the treatments showed isometric growth, implies that all the groups were in good condition.. The present work also revealed that Nile tilapia followed the cube law completely in all groups of fish in which their values were close to the theoretical value ($b = 3$). The length-weight relationship was found to be in a linear form conforming to the general formula expressing the relationship between the length and weight of fishes. This could be due to the fact that the length-weight relationship of fish varies depending upon the condition of life in the aquatic environment (Ighwel *et al.*, 2011), but it is an important tool that gives information on the growth pattern of animals. In conclusion, 60 mg MT/kg diet can be considered as an optimal dose for Nile tilapia sex reversal along with its optimum growth and feed utilization performances.

Authorship contribution Statement

Berhanu B, Workagegn KB, Pavanasam N: Conceptualization, methodology development, visualization, data analysis and writing up of the manuscript. Workagegn KB, and P Natarajan supervision, validation, formal analysis, writing, reviewing and editing of the manuscripts

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