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Full Length Research Paper

Production of salinity tolerant tilapia through interspecific hybridization between Nile tilapia (*Oreochromis niloticus*) and red tilapia (*Oreochromis* sp.)

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The present work aims to produce a salinity tolerant fish through interspecific hybridization of Nile tilapia, *Oreochromis niloticus* × Red tilapia, *Oreochromis* sp. Growth performance, proximate body composition and feed utilization of the offspring produced of Nile tilapia, red tilapia and their diallelic interspecific hybridization under different salinity levels were evaluated and heterosis values were estimated for weight gain and specific growth rate. The results of most of the productive performance traits and heterosis values indicated a maternal effect and suggest that the hybrid of (♀ Red tilapia × ♂ Nile tilapia) can be produced and reared at different salinity levels up to 32 ppt, as economic value compared to purebreds and reciprocal hybrid.

Key words: Salinity tolerance, Nile tilapia, red tilapia, productive performance, heterosis, interspecific hybridization.

INTRODUCTION

Tilapia aquaculture is rapidly expanding with a global production of about 2.8 million metric tons in 2008 (FAO, 2010) and estimated to increase to 8.89 million metric tons by the year 2020 (Tacon and Metian, 2008). Nile tilapia, *Oreochromis niloticus*, is one of the most important fresh water finfish in aquaculture (Kamal and Mair, 2005). It grows fast but it less salinity tolerant compared to other tilapias (Avella et al., 1993; Hulata, 2001). The shortage in freshwater in many countries, together with the competition for it with agriculture and other urban activities has increased the pressure to develop aquaculture in brackish water and sea water (El-Sayed, 2006).

The Florida red tilapia (FRT) descended from a cross between *Oreochromis urolepis hornorum* females and *Oreochromis mossambicus* males, which were described by (Hickling, 1960) while conducting experiments on hybrid tilapia crosses. In the 1970s Natural Systems, a

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Florida based company developed the hybrid cross into a commercially available variety (Rakocy et al., 1993). It is assumed that the salinity tolerance of FRT is directly related to its parental species' tolerances. *O. mossambicus* is among the most salt tolerant of tilapia species, with documented reproduction in experimental production ponds at 49 ppt and survival at 64 ppt (Potts et al., 1967). In contrast, *O. urolepis hornorum* has been observed to survive salinities as high as 35 ppt in seawater ponds (Fryer and Iles, 1972). The FRT exhibits fecundity that has been attributed to its parental species sharing a close ancestry (Hickling, 1960). Red tilapias (a collective name for the large number of red, orange, gold and pink phenotypes) have become objects of interest for culturist and researchers throughout the world (Wohlfarth and Hulata, 1983).

Interspecific hybrid fish have been produced for aquaculture and stocking programmes to increase growth rate, transfer desirable traits between species, combine desirable traits of two species into a single group of fishes, reduce unwanted reproduction through production of sterile fish or mono-sex offspring, take advantage of sexual dimorphism, increase harvest ability, increase environmental tolerances, and to increase overall hardiness in culture conditions (Lahav and Ra'anan, 1997; Stickney, 2000; Bartley et al., 2001; Hallerman, 2002). The present study aimed to produce a salinity tolerant tilapia through interspecific hybridization between red tilapia and Nile tilapia. In addition, the growth performance, proximate body composition and feed utilization of the offspring produced of red tilapia, Nile tilapia and their diallelic hybridization reared under different salinity levels were studied, and heterosis values were also estimated for weight gain and specific growth rate.

MATERIALS AND METHODS

The present study was carried out at the experimental Fish farm and the Laboratory of Breeding and Production of Fish, Animal and Fish Production Department, Faculty of Agriculture (Saba-Bacha), Alexandria University, Alexandria, Egypt.

Fish origin

The Nile tilapia was obtained from the Middle East Fish Farm, Tolombat Halk El-Gamal, El-Behera Governorate, Egypt. The red tilapia, *Oreochromis* sp. used in this study was a hybrid descendant of an original cross of female (*O. mossambicus*) × male (*O. niloticus*) and obtained from the Marine Fish Hatchery of GAFRD, Alexandria, Egypt.

Interspecific hybridization

Ripe females and males with an average live weight of *O. niloticus* (60.20 ± 1.30 and 73.50 ± 1.45 g) and red tilapia, *Oreochromis* sp. (65.00 ± 1.20 and 69.70 ± 1.90 g), respectively, were selected. Strains of *O. niloticus* and red tilapia, *Oreochromis* sp. and their diallel crosses were stocked for natural spawning in separated concrete ponds (3 × 1 × 1.2 m) at a rate of 4 breeders/ m^3. The sex ratio of the fish was 3 females: 1 male. Brood fish were fed twice daily on pellet diet containing 26% protein at satiation for 6 days a week. Post-hatching fry of *O. niloticus* and red tilapia, *Oreochromis* sp. and their diallelic crosses were collected and transferred separately to laboratory experimental glass aquaria (100 liter volume). The fry acclimation to laboratory conditions were counted and weighed. Each aquarium was supplied with dechlorinated tap water and adequate continuous aeration systems, cleaned once daily by siphoning and was replaced one-half to two thirds of their water volume. Fry were fed three times daily on pellet diet containing 38% protein to satiation, six days a week for 60 days. Then all fish were fed on diet containing 32% to satiation six days a week for another 45 days. Formulations of the different diets used in the present study were prepared according to El-Zaeem (2001). Fish were weighed biweekly for 105 days experimental period.

Base generation (F_0)

Culture conditions

Base generation (F_0) offspring produced from interspecific hybridization were collected, counted and weighed. Then, fry were transferred separately to glass aquaria (total area 100 × 34 × 50 cm) at a rate of 1 fish/10 L, and divided randomly for subjected to different salinity treatments. The glass aquaria were supplied with fresh dechlorinated tap water and supplemental aeration. Water temperatures were maintained at 28.00 ± 1.00°C.

Saline water acclimation

Two different salinity levels of (16 and 32 ppt) were made by mixing freshwater with crude natural salt (Likongwe, 2002) obtained from El-Nasr Company for salt, Borg El-Arab, Alexandria, Egypt, beside a third group of freshwater as control. Fry obtained from *O. niloticus*, red tilapia, *Oreochromis* sp. and their diallelic crosses, were gradually acclimated to the respective treatment of salinities by raising the salinity at the rate of 4 ppt daily (Watanabe and Kuo, 1985). Then, water in each glass aquaria was partially changed once daily and totally every three days. Fry were fed three times daily on pellet diet containing 38% protein to satiation six days a week for 60 days. Then all fish were fed on diet containing 32% to satiation six days a week to the end of experiment. Fish were weighed biweekly for 105 days. The different salinities were maintained throughout the experimental period with salinity monitored daily using salinity refractometer (S/Mill-E, ATAGO Co., LTD).

Quantitative traits measurements

The following parameters were measured: initial and final body weight (g), specific growth rate (SGR %/day), feed intake, feed conversion ratio (FCR) and protein efficiency ratio (PER). Furthermore, initial and final body composition analyses were performed for moisture, crude protein and lipid contents according to the standard A.O.A.C (1984) methods.

Heterosis

Heterosis was expressed in percentage by the formula reported by Nguenga et al. (2000):

Heterosis (H%)= [(C1 + C2)/2 – (P1 + P2)/2] / [(P1 + P2)/2] × 100

Where C1 and C2 are the mean weight gains or SGR %/day of crossbreeds, and P1 and P2 are the mean weight gains or SGR %/day of the purebreds.

Statistical analysis

Data were analyzed using the following model (Costat, 1986):

$$Y_{ijk} = \mu + T_i + S_j + (TS)_{ij} + B_k + e_{ijk}$$

Where: Y_{ijk}, Observation of the ijkth parameter measured; μ, overall mean; T_i, effect of ith species; S_j, effect of Jth salinity; $(TS)_{ij}$, interaction species by salinity; B_k, effect of Kth block; e_{ijk}, random error. For proximate body composition data at the beginning of experimental fish, data were analyzed by fitting the following model (Costat, 1986):

$$Y_{ij} = \mu + T_i + e_{ij}$$

Where: Y_{ij}, Observation of the ijth parameter measured; μ, overall mean; T_i, effect of ith species; e_{ij}, random error. The significant differences (P≤0.05) among means were tested by the method of Duncan (1955).

RESULTS AND DISCUSSION

The results of growth performance showed that there are no significant differences in initial body weight among the different genotypes of fish. The highest values of final body weight (FBW) and weight gain were recorded for red tilapia, but did not differ significantly (P≤0.05) from that of the hybrid (♀Nile tilapia × ♂Red tilapia). The highest value of SGR was achieved for the hybrid (♀Red tilapia × ♂Nile tilapia), but did not differ significantly (P≤0.05) from those of red tilapia and the hybrid (♀Nile tilapia × ♂Red tilapia). The highest significant values (P≤0.05) of FBW and WG were recorded for fish reared at freshwater compared to fish reared at salinity levels of 16 and 32 ppt. In addition, the highest value of SGR were observed by fish reared at freshwater but did not differ significantly (P≤0.05) from that of fish reared at 16 ppt. The results of FBW and WG of the hybrid (♀Nile tilapia × ♂Red tilapia) reared at freshwater had improved significantly (P≤0.05) compared with the other genotypes of fish reared at different levels of salinity, but did not differ significantly (P≤0.05) from those of red tilapia and the hybrid (♀Red tilapia × ♂Nile tilapia) reared at 16 ppt. The highest significant value (P≤0.05) of SGR was observed for the hybrid (♀Red tilapia × ♂Nile tilapia) reared at 16 ppt, but did not differ significantly (P≤0.05) from those of all fish reared at fresh water and red tilapia and the hybrid (♀Nile tilapia × ♂Red tilapia) reared at 16 ppt, and the hybrid (♀Red tilapia × ♂Nile tilapia) reared at 32 ppt (Table 1).

In this connection, El-Zaeem et al. (2010) reported that salinity tolerance tilapia hybrid can be produced through interspecific hybridization between *O. niloticus* and *O. aureus*. The productive performance traits of (♀ *O. niloticus* × ♂ *O. aureus*) and ♀ *O. aureus* × ♂ *O. niloticus*) had significant superiority (P≤0.05) in most of these traits at freshwater, 16 and 32 ppt compared to either *O. niloticus* or *O. aureus*. Most of the productive performance traits of *O. niloticus*, (♀ *O. niloticus* × ♂ *O. aureus*) and (♀ *O. aureus* × *O. niloticus* ♂) had significantly decreased (P≤0.05) with increasing salinity levels. Moreover, *O. aureus* showed more salinity tolerance and superiority (P≤0.05) of feed utilization and survival rate at salinity level of 32 ppt compared with the other genotypes of fish at the same salinity level. Suresh and Lin (1992) indicated that a range of 10 to 20 ppt was optimal for tilapia growth. The results of the present work manifested that the hybrid obtained from hybridization of (♀ Nile tilapia × ♂ Red Tilapia) and (♀Red Tilapia × ♂Nile Tilapia) had significant superiority of growth performance under different levels of salinity up to 32 ppt compared with *O. niloticus* at the same salinity levels. Haroun (1999) also reported that the hybrid of (♀Red Tilapia × ♂Nile Tilapia) showed a superior growth in weight, length and specific growth rate compared to the purebreds. The results of the present work are consistent with these findings.

Although both two hybrids displayed a positive heterosis for weight gain and SGR%/day compared to the pure breeds at different salinity levels, the hybrid of (♀Red tilapia x ♂Nile tilapia) reared at 16 and 32 ppt showed higher positive heterosis (Table 2). These results are consistent with findings reported by Haroun (1999). In addition, the positive heterosis values for weight gain and specific growth rate showed that a positive interaction has occurred between the parental genes found at different loci in the inter-generic hybrid genome as reported by Sheridan (1981). The phenotypic variance of a quantitative trait such as growth is governed by the genetic variance, environmental variance and the interaction between the genetic and environmental variance (Tave, 1993). A positive interaction between the genetic variance of the hybrid and the environment may have led to good phenotypic expression of growth the hybrid (♀Red tilapia x ♂Nile tilapia) under different levels of salinity compared to fresh water (Table 2).

Moreover, at the beginning of experiment, the highest significant value (P≤0.05) of protein was recorded for red tilapia compared to the other genotypes of fish, while no significant differences in moisture and lipid content were detected among red tilapia, Nile tilapia and their reciprocal hybrids. At the end of experiment, the highest significant values (P≤0.05) of moisture and lipid contents were recorded for red tilapia compared to the other genotypes of fish. Also, the highest significant value (P≤0.05) of protein was observed for red tilapia but did not differ significantly (P≤0.05) from that of Nile tilapia. No significant differences in moisture and protein were detected among the fish reared at different salinity levels.

Table 1. Growth performance of red tilapia, Nile tilapia and their diallelic crosses at different salinity levels.

Treatment	Initial body weight (g)	Final body weight (g)	Weight gain (g)	SGR%/ day
Genotype				
Red Tilapia (R)	0.40	29.17^{a}	28.79^{a}	4.10^{ab}
Nile Tilapia (N)	0.33	15.60^{c}	15.27^{c}	3.61^{b}
♀ R × ♂ N	0.25	27.55^{b}	27.30^{b}	4.59^{a}
♀ N × ♂ R	0.32	27.77^{ab}	27.46^{ab}	4.24^{a}
Salinity (ppt)				
Fresh water (FW)	0.32	30.85^{a}	30.53^{a}	4.41^{a}
16 ppt	0.32	29.04^{b}	28.72^{b}	4.30^{a}
32 ppt	0.33	15.18^{c}	14.87^{c}	3.70^{b}
Genotype × Salinity				
R-FW	0.38 ± 0.19	33.38 ± 1.73^{bc}	33.00 ± 1.93^{bc}	4.32 ± 0.55^{abcd}
N-FW	0.33 ± 0.01	22.68 ± 0.11^{d}	22.35 ± 0.09^{d}	4.02 ± 0.04^{abcde}
♀ R × ♂ N-FW	0.25 ± 0.18	30.98 ± 1.52^{c}	30.73 ± 1.34^{c}	4.74 ± 0.71^{abc}
♀ N × ♂ R-FW	0.32 ± 0.15	36.36 ± 0.37^{a}	36.05 ± 0.22^{a}	4.57 ± 0.45^{abcd}
R-16 ppt	0.39 ± 0.19	35.47 ± 2.03^{ab}	35.09 ± 1.83^{ab}	4.37 ± 0.44^{abcd}
N-16 ppt	0.33 ± 0.01	14.38 ± 0.25^{g}	14.05 ± 0.26^{g}	3.59 ± 0.06^{de}
♀ R × ♂ N-16 ppt	0.25 ± 0.17	34.61 ± 2.14^{ab}	34.37 ± 1.96^{ab}	4.82 ± 0.65^{a}
♀ N × ♂ R-16 ppt	0.33 ± 0.15	31.71 ± 0.43^{c}	31.39 ± 0.28^{c}	4.42 ± 0.42^{abcd}
R-32 ppt	0.43 ± 0.12	18.68 ± 0.25^{e}	18.30 ± 0.45^{e}	3.62 ± 0.28^{cde}
N-32 ppt	0.33 ± 0.01	9.76 ± 0.06^{h}	9.43 ± 0.04^{h}	3.23 ± 0.04^{e}
♀R × ♂ N-32 ppt	0.24 ± 0.17	17.05 ± 0.07^{ef}	16.81 ± 0.11^{ef}	4.20 ± 0.74^{abcde}
♀ N × ♂ R-32 ppt	0.31 ± 0.14	15.25 ± 0.21f^{g}	14.94 ± 0.36^{fg}	3.75 ± 0.49^{bcde}

Means within each comparison in the same column with the different superscripts differ significantly (P≤0.05). Initial and final body weight (IBW and FBW) = body weight at start and end of experiment. Specific growth rate (SGR % /day) = (Ln final weight - Ln initial weight) / number of days (100).

Table 2. Heterosis (H%) values of the weight gain and SGR%/day of the interspecific hybridization between red tilapia and Nile tilapia.

Parameter	H%[1]	H% (♀R x ♂N)[2]	H% (♀N x ♂R)[3]
Fresh water			
WG	20.65	11.04	30.26
SGR%/day	11.63	13.67	9.59
16 ppt			
WG	33.82	39.89	27.76
SGR%/day	16.08	21.11	11.06
32 ppt			
WG	14.50	21.24	7.75
SGR%/day	16.06	22.63	9.49

[1]General heterosis; [2]heterosis according to the mean of performance of F1 from the hybrid of (♀R × ♂N); [3]heterosis according to the mean of performance of F1 from the hybrid of (♀N × ♂R).

While, the highest significant value (P≤0.05) of lipid was recorded for fish reared at 32ppt. The highest significant value (P≤0.05) of moisture was recorded for red tilapia reared at 32ppt, but did not differ significantly (P≤0.05) from that of red tilapia reared at 16 ppt. The highest significant value (P≤0.05) of protein was achieved for red

Table 3. Body composition of red tilapia, Nile tilapia and their diallelic crosses at different salinity levels.

Treatment	Moisture	Percentage (%) on dry matter basis	
		Protein	Lipid
Genotype		At the start	
Red Tilapia (R)	78.69	55.65[a]	17.5
Nile Tilapia (N)	78.36	54.37[b]	17.96
♀ R × ♂ N	80.45	53.70[b]	18.28
♀ N × ♂ R	78.11	54.15[b]	18.88
Genotype		At the end	
Red Tilapia (R)	76.01[a]	57.25[a]	25.20[a]
Nile Tilapia (N)	74.90[bc]	56.97[ab]	24.28[c]
♀ R × ♂ N	75.31[b]	56.56[b]	24.81[b]
♀ N × ♂ R	74.54[c]	56.68[b]	24.72[b]
Salinity (ppt)			
Fresh water (FW)	74.99	56.78	24.58[b]
16 ppt	75.25	57.1	24.59[b]
32 ppt	75.32	56.73	25.09[a]
Genotype × Salinity			
R-FW	75.32 ± 0.03[cd]	57.21 ± 0.30[ab]	25.34 ± 0.23[c]
N-FW	74.85 ± 0.49[cd]	56.93 ± 0.67[abc]	24.10 ± 0.18[i]
♀ R × ♂ N-FW	75.27 ± 0.09[cd]	56.41 ± 0.06[c]	24.49 ± 0.22[gh]
♀ N × ♂R-FW	74.54 ± 0.13[d]	56.57 ± 0.77[bc]	24.42 ± 0.23[h]
R-16 ppt	76.22 ± 0.40[ab]	57.67 ± 0.16[a]	24.63 ± 0.11[f]
N-16 ppt	75.05 ± 0.35[cd]	56.97 ± 0.22[abc]	24.55 ± 0.07[fg]
♀ R × ♂ N-16 ppt	75.12 ± 1.10[cd]	56.99 ± 0.16[abc]	24.16 ± 0.08[i]
♀ N × ♂ R-16 ppt	74.63 ± 1.00[d]	56.78 ± 0.31[bc]	25.01 ± 0.16[d]
R-32 ppt	76.50 ± 0.47[a]	56.89 ± 0.01[abc]	25.63 ± 0.25[b]
N-32 ppt	74.80 ± 0.28[cd]	57.03 ± 0.11[abc]	24.18 ± 0.42[i]
♀R × ♂ N-32 ppt	75.54 ± 0.23[bc]	56.29 ± 0.26[c]	25.79 ± 0.03[a]
♀ N × ♂ R-32 ppt	74.45 ± 0.15[d]	56.71 ± 0.08[bc]	24.75 ± 0.15[e]

Means within each comparison in the same column with the different superscripts differ significantly (P≤0.05).

tilapia reared at 16 ppt but did not differ significantly (P≤0.05) from those of red tilapia and Nile tilapia reared at freshwater and Nile tilapia and the hybrid (♀Red tilapia x ♂Nile tilapia) reared at 16 ppt and red tilapia and Nile tilapia reared at 32 ppt.

Furthermore, the highest significant value (P≤0.05) of lipid was recorded for the hybrid (♀Red tilapia × ♂Nile tilapia) reared at 32 ppt compared to the other genotypes reared at different salinity levels (Table 3). Brolongan and Benitez (1992) found insignificant differences in total lipids content in all organs of milk fish (*Chanos chanos*) reared at fresh water or sea water, while moisture content increased significantly with increasing salinity levels. Likongwe (2002) reported that crude protein values of *Oreochromis shiranus shiranus* cultured at 0, 10 and 20 ppt of salinity were 49.18, 55.23 and 52.39%, respectively. The decreased body protein at high level of salinity (up to 20 ppt) may be due to the increase in energy demand for osmoregulation and fish may utilize protein as source of energy at these levels of salinity. These findings are consistent with the results obtained during the present work.

In addition, the highest value of feed intake was recorded for red tilapia which was significantly (P≤0.05) higher than those of the other genotypes. The best values of FCR and PER were recorded for the hybrid (♀Red tilapia × ♂Nile tilapia), but did not differ significantly (P≤0.05) from those of red tilapia and the hybrid (♀Nile tilapia × ♂Red tilapia). The highest significant value (P≤0.05) of feed intake was recorded for fish reared at freshwater compared with the other fish reared at different salinity levels. The best and highest

Table 4. Feed utilization of red tilapia, Nile tilapia and their diallelic crosses at different salinity levels.

Treatment	Feed intake (g)	FCR	PER
Genotype			
Red Tilapia (R)	60.17[a]	2.13[b]	1.58[a]
Nile Tilapia (N)	36.17[c]	2.38[a]	1.41[b]
♀ R × ♂ N	56.16[b]	2.13[b]	1.59[a]
♀ N × ♂ R	56.50[b]	2.17[b]	1.58[a]
Salinity (ppt)			
Fresh water (FW)	61.88[a]	2.07[b]	1.64[a]
16 ppt	58.00[b]	2.04[b]	1.64[a]
32 ppt	36.87[c]	2.50[a]	1.34[b]
Genotype × Salinity			
R-FW	67.50 ± 0.71[ab]	2.05 ± 0.14[def]	1.63 ± 0.11[bcd]
N-FW	54.00 ± 1.40[d]	2.42 ± 0.05[bc]	1.38 ± 0.03[efg]
♀ R × ♂ N-FW	62.01 ± 2.83[c]	2.02 ± 0.18[def]	1.66 ± 0.15[bc]
♀ N × ♂R-FW	64.00 ± 1.41[bc]	1.78 ± 0.03[f]	1.88 ± 0.03[a]
R-16 ppt	70.51 ± 0.71[a]	2.01 ± 0.13[def]	1.66 ± 0.10[bc]
N-16 ppt	30.50 ± 0.70[f]	2.17 ± 0.01[cd]	1.54 ± 0.01[cdef]
♀ R × ♂ N-16 ppt	64.49 ± 2.12[bc]	1.88 ± 0.17[ef]	1.78 ± 0.16[ab]
♀ N × ♂ R-16 ppt	66.50 ± 2.10[ab]	2.12 ± 0.05[de]	1.58 ± 0.04[bcde]
R-32 ppt	42.47 ± 3.54[e]	3.33 ± 0.25[a]	1.44 ± 0.16[defg]
N-32 ppt	24.00 ± 1.42[g]	2.55 ± 0.13[b]	1.31 ± 0.07[g]
♀R × ♂ N-32 ppt	42.00 ± 1.40[e]	2.50 ± 0.07[b]	1.34 ± 0.04[fg]
♀ N × ♂ R-32 ppt	39.00 ± 1.35[e]	2.61 ± 0.03[b]	1.28 ± 0.01[g]

Means within each comparison in the same column with the different superscripts differ significantly (P≤0.05). Feed conversion ratio (FCR) = dry feed intake / gain. Protein efficiency ratio (PER) = gain / protein intake.

FCR and PER were recorded for fish reared at 16 ppt, but did not differ significantly (P≤0.05) from that of fish reared at freshwater. The highest significant value (P≤0.05) of feed intake was recorded for red tilapia reared at 16 ppt, but did not differ significantly (P≤0.05) from those of red tilapia reared at freshwater and the hybrid (♀Nile tilapia × ♂Red tilapia) reared at 16 ppt. The poorest significant value (P≤0.05) of FCR was recorded for red tilapia reared at 32 ppt compared with the other genotypes of fish reared at different salinity levels. Moreover, the protein efficiency ratio (PER) of the hybrid (♀Nile tilapia × ♂Red tilapia) reared at freshwater increased significantly (P≤0.05) compared to the other genotypes of fish reared at different salinity levels, but did not differ significantly (P≤0.05) from that of the hybrid (♀Red tilapia × ♂Nile tilapia) reared at 16 ppt (Table 4). Haroun (1999) reported that maximum feed utilization was obtained by the hybrid of (♀Red tilapia × ♂ Nile tilapia) compared with pure fish and can be used successfully in brackish water (15 ppt) or salt water (up to 25 ppt). The results of the present work are consistent with these findings.

The results of most of the productive performance traits and heterosis values of weight gain and specific growth rate infer that there is a maternal effect and suggest that the hybrid of (♀ Red tilapia × ♂ Nile tilapia) can be produced and reared at different salinity levels up to 32 ppt as economic value compared with their parents.

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REFERENCES

A.O.A.C (Association of Official Analytical Chemists) (1984). Official methods of analysis (14th ed). Inc., Arlington, Virginia, USA.

Avella M, Berhaut J, Bornancin M (1993). Salinity tolerance of two tropical fishes, *Oreochromis aureus* and *Oreochromis niloticus*, 1: Biochemical and morphological changes in the gill epithelium. J. Fish Biol., 42: 243-254.

Bartley DM, Rana K, Immink AJ (2001). The use of inter-specific hybrids in aquaculture and fisheries. Rev. Fish Biol. Fish., 10: 325-337.

Brolongan I, Benitez L (1992). Lipid and fatty acid composition of milkfish (*Chanos chanos* Forsskal) grown in freshwater and seawater. Aquacult., 104: 79-89.

CoStat (1986). CoStat 3.03, Copyright, Co Hort Software. All rights reserved. P.O. Box 1149, Berkeley, CA 94701, USA.

Duncan DB (1955). Multiple ranges and multiple F test. Biom. 11: 1-42.

El-Sayed AM (2006). Tilapia culture in salt water: Environmental requirements, Nutritional implications and Economic potentials. En: Editores: L. Elizabeth Cruz Suarez, Denis Ricque Marie, Mireya Tapia Salazar, Martha G. Nieto Lopez, David A. Villarreal Cavazos, Ana C. Puello Cruz Y Armando Garcia Ortega. Avances en Nutricion Acuicola VIII. VIII Simposium Internacional de Nutricion Acuicola. 15-17 Noviembre. Universidad Autonoma de Nuevo Leon, Monterrey, Nuevo Leon, Mexico. ISBN 970-694-333-5, 95-106.

El-Zaeem SY (2001). Breeding studies in Tilapia. Ph.D. Thesis. Faculty of Agriculture (Saba-Basha), Alex. Univ., Egypt.

El-Zaeem SY, Salama ME, El-Maremie HAT (2010). Production of salinity tolerance Nile tilapia, *Oreochromis niloticus* through traditional and modern breeding methods: I- Application of inter-specific crossbreeding with Blue tilapia, *Oreochromis aureus*. Egypt. J. Aquat. Biol. Fish, 14 (1): 57-74.

FAO (2010). Food and Agricultural Organization,. Fisheries Statistics. www.fao.org/fishery/statistics. (accessed on 10 July 2010).

Fryer G, Iles TD (1972). The Cichlid Fishes of the Great Lakes of Africa-Their Biology and Evolution. Oliver and Boyd, Edinburgh, Scotland.

Hallerman EM (2002). Genetic improvement of tilapia at commercial RAS. Global. Aquacult. Advocate, 5: 16-17.

Haroun MR (1999). Cross-breeding Egyptian Races of Tilapias to Produce More Productive Hybrids. Ph.D. Thesis. Faculty of Science. Tanta. University, Egypt.

Hickling CF (1960). The malacca *Tilapia* hybrids. J. Genet., 57: 1-10.

Hulata G (2001). Genetic manipulation in aquaculture: a review of stock improvement by classical and modern technologies. Genet., 111: 155-173.

Kamal AMdM, Mair GC (2005). Salinity tolerance in superior genotypes of tilapia, *Oreochromis niloticus*, *Oreochromis mossambicus* and their hybrids. Aquacult. 247: 189-201.

Lahav E, Ra'anan Z (1997). Salinity tolerance of genetically produced tilapia (*Oreochromis*) hybrids. Bamidgeh. 49: 160-165.

Likongwe JS (2002). Studies on potential use of salinity to increase growth of tilapia in aquaculture in malawai. In: K.McElwee, K.Lewis., M.Nidiffer, and P. Buitrago (EDs.), Nineteenth Annual Technical Report. Pond Dynamics/Aquaculture CRSP, Oregon State University, Corvallis, Oregon.

Nguenga D, Teugels GG, Ollevier F (2000). Fertilization, hatching, survival and growth rates in reciprocal crosses of two strains of an African catfish, *Heterobranchus bidorsalis*, under controlled hatchery conditions. Aquacult. Res., 31: 565-373.

Potts WTW, Toster MA, Rudy PP, Hewells GP (1967). Sodium and water balance in the cichlid teleost *Tilapia mossambica*. J. Exp. Biol., 47: 461-470.

Rakocy JE, Hargreaves JA, Bailey DS (1993). Comparison of tilapia species for cage culture in the Virgin Islands. UVI Research 5:13-17.

Sheridan AK (1981). Crossbreeding and heterosis. Anim. Breed. Abs., 49: 131-144.

Stickney RR (2000). Status of research on tilapia. Pages. 23-26 in B.A. Costa-Pierce and J.E. Rakocy, editors. Tilapia Aquaculture in the Americas, Vol. 2. The World Aquaculture Society, Baton Rouge, Louisiana.

Suresh AV, Lin CK (1992). Tilapia culture in saline waters: a review. Aquacult., 106: 201-226.

Tacon AGJ, Metian M (2008). Global overview on the use of fish meal and fish oil in industrially compounded aquafeeds: Trends and future prospects. Aquacult., 285: 14-158.

Tave D (1993). Genetic for Fish Hatchery Mangers. Second edition Van Nostrand Reinhold New York 415 pp.

WO, Kuo CM (1985). Observation on reproductive performance of Nile tilapia (*Oreochromis niloticus*) in laboratory aquaria at various salinities. Aquacult., 49: 315-323.

Wohlfarth G, Hulata G (1983). Applied genetics of tilapias. ICLARM studies and reviews 6. International Center for Living Aquatic Resources Management, Manila, Philippines.