

Reproductive Indices of Saline-tolerant Tilapia Strains, *Oreochromis* Spp. and Their Crosses

¹Cecilia J. Jaspe and ²Christopher Marlowe A. Caipang

¹Brackishwater Aquaculture Center, Institute of Aquaculture, College of Fisheries and Ocean Sciences, University of the Philippines Visayas, Iloilo, Philippines

²Faculty of Biosciences and Aquaculture, University of Nordland, Bodø 8049, Norway

Abstract: The aim of the study was to determine the total fecundity, relative fecundity and Gonadosomatic Index (GSI) in the F₁ female of the different saline-tolerant strains of tilapia, namely, *Oreochromis mossambicus*, a tilapia hybrid (*O. spilorus* x *O. niloticus* GIFT x *O. aureus*) and their crosses. There were no significant differences in the length and weight of the female spawners among the tilapia strains. Higher total fecundity was observed in bigger-sized fish, whereas the relative fecundity is significantly higher in the smaller-sized fish. Total fecundity and GSI significantly varied among the tilapia strains, while there was no significant difference in relative fecundity. Both total length and body weight were positively correlated with total fecundity in the tilapia hybrid strain and their crosses. However, the degree of correlation was not significantly different. Relative fecundity was negatively correlated with total length and body weight, and the degree of correlation was significantly different in the *O. mossambicus* strain.

Key words: Fecundity, *Oreochromis* spp., reproductive performance, saline-tolerant strains

INTRODUCTION

Tilapia is a freshwater fish that is considered to be an important food fish because it serves as a major protein source in many countries. Due to the many favourable characteristics of this fish, e.g., tolerance to adverse environmental conditions and fast growth rates with high potential yield (Ridha, 2004), its culture is increasingly popular worldwide with an average annual growth rate of 14% since 1984 (Getinet, 2008). Tilapias are now the second most popular farmed fish after carps.

Nile tilapia, *Oreochromis niloticus* remains the widely cultured tilapia species as its production accounts for almost 75% of the total volume. However, the expansion of commercial tilapia culture is hampered by the shortage of fry production to meet the seasonal demands as well as low fecundity and asynchronous spawning. There have been techniques that were developed to alleviate the problems of low fecundity and asynchronous spawning. These include manipulation of environmental conditions (Ridha and Cruz, 2000), frequency of seed removal (Ridha and Cruz, 1998) and dietary manipulation (Siddiqui *et al.*, 1997).

Even though Nile tilapia is a popular species for culture, it is not a saline-tolerant species (Kamal and Mair, 2005), rendering it unfavourable to culture in brackishwater and seawater environments. On the other hand, Mozambique tilapia, *Oreochromis mossambicus*,

has been reported to withstand extremely high salinities (Hwang *et al.*, 1989), and is regarded as one of the most saline tolerant fish species.

The development of saline-tolerant strains/hybrids resulted from initial observations that when tilapias were stocked in ponds together with shrimp, the incidence of outbreaks of the luminous vibriosis due to *Vibrio harveyi* was decreased (Cruz *et al.*, 2008). Later studies have also shown that effluent water from tilapia contained substances that are antagonistic to *V. harveyi* (Tendencia *et al.*, 2004, 2005). The tilapias used in high-saline culture are the hybrid strains, particularly the hybridization of a tilapia strain with a saline tolerant *O. mossambicus* (Stickney, 1986). The hybrid strains commonly used for high-saline culture are the red tilapia (Eguia, 1996), a cross between a male *Tilapia hornorum* and a female *O. niloticus* and a sex-reversed hybrid of the *O. niloticus* and *O. mossambicus* (Cruz *et al.*, 2008). Despite the development of these hybrids that are adapted for high-saline culture, there are still research efforts to develop tilapia strains specifically suitable for culture in brackishwater environments, including the evaluation of other tilapia species and their hybrids.

Previously, we developed a breeding program for the production of saline-tolerant tilapia hybrids using different strains that are locally available. We produced a saline-tolerant tilapia hybrid by crossing *O. mossambicus* with another hybrid, *Oreochromis spilorus* x *O. niloticus*

GIFT × *O. aureus*. Results showed that the offspring of the crosses regardless of the sex of the parental strain were able to tolerate high salinity levels up to 50 ppt with no mortalities (Jaspe *et al.*, 2007). However, there is no data on the fecundity of the saline-tolerant hybrids as the information is necessary to ensure that there is sufficient number of broodstock to be maintained for the continuous supply of fry during the culture period. In order to refine the breeding program for the production of saline-tolerant hybrids, the objective of the study was to determine the egg production of the parental tilapia strains and their hybrids. We collected mature eggs from the female spawners of the F₁ of the parental strains (*O. mossambicus* and the tilapia hybrid, *Oreochromis spilorus* × *O. niloticus* GIFT × *O. aureus*) and their crosses. Selected reproductive parameters including total fecundity, relative fecundity and Gonadosomatic Index (GSI) were derived and correlated these with total length and body weight of the fish. The data generated in this study will be useful in future breeding programs for saline-tolerant tilapias.

MATERIALS AND METHODS

Experimental facilities: Breeding units consisting of 1 m³ hapas (fine-meshed breeding nets) were installed in 20 m³ concrete tanks. Water was obtained from a rainwater-filled reservoir supplied by gravity to the experimental facilities. The facilities are located at the Brackishwater Aquaculture Center of the College of Fisheries and Ocean Sciences, University of the Philippines Visayas.

Sources of experimental fish: The study was conducted from January-June, 2006. The fish were obtained from batches of the crosses in our previous study (Jaspe *et al.*, 2007). *Oreochromis mossambicus* were taken from the holding ponds of the research center, while the tilapia hybrid, which is a cross of *O. spilorus* × *O. niloticus* GIFT × *O. aureus*, were purchased from a commercial tilapia farm in Negros Occidental, Philippines. These two tilapia strains are tolerant to high salinity levels even at full seawater (35 ppt) as shown in an earlier study (Jaspe *et al.*, 2007). The broodstock were maintained in outdoor tanks of the research center and supplied with flow-through freshwater and ample aeration.

Determination of egg production: There were four treatment groups: Treatment 1: female spawners from F₁ of *O. mossambicus* parental strain, Treatment 2: female spawners from F₁ of the tilapia hybrid parental strain, Treatment 3: female spawners from F₁ of the cross between *O. mossambicus* (female) × tilapia hybrid (male) and Treatment 4: female spawners from F₁ of the cross between *O. mossambicus* (male) × tilapia hybrid (female).

To determine whether the size of the spawners will have an effect on egg production, female spawners in

Table 1: Length and weight (Mean±SD) of the female spawners used in the study

	Length (mm)	Weight (g)
Treatment 1	134.78±7.72	39.79±7.85
Treatment 2	136.20±8.66	43.70±9.50
Treatment 3	128.90±20.09	39.50±19.20
Treatment 4	125.30±18.24	36.70±17.30

each treatment were subdivided into three batches, namely small-sized (30-40 g), medium-sized (41-50 g) and large-sized group (more than 51-70 g). Each treatment consisted of eighteen female spawners divided into six fish for each size group.

Individual female spawner in each treatment was scooped out of the water and placed in a bucket of freshwater containing 2-phenoxyethanol (Sigma, UK) at a concentration of 1:20,000 (v/v) (Coward and Bromage, 1999). Once the fish was completely anesthetized, it was immediately weighed and its total length was measured. The ventral portion of the fish was dissected and mature eggs were carefully removed and weighed. A portion of the egg clutch (0.1-0.2 g) was taken, weighed and the number of eggs was counted to determine the total fecundity for each fish. Fecundity was estimated from total counts of eggs in the ovaries of the fish in the most advanced stage of development (Njiru *et al.*, 2006). Relative fecundity, expressed as the number of eggs per unit body weight, was determined by dividing the total number of mature eggs produced with the total body weight of the particular female spawner. The weight of the gonad relative to the total body weight, i.e., the Gonadosomatic Index (GSI) was calculated as: GSI = weight of the ovary/total body weight of the fish) × 100.

Statistical analysis: Total length, body weight, total fecundity, relative fecundity and gonadosomatic index data were expressed as mean±S.D. Analysis of variance (ANOVA) was used to determine differences among the treatment groups. If the differences were significant, the Student's *t*-test was further used for the analysis. Simple correlation analysis (*r*) was used to determine the degree of relationship between the variables tested. Data were log₁₀ or Arc-sine transformed when appropriate. Levels of significance were set at *p*<0.05. All statistical computations were done using a statistical software (Systat ver 8.0, Chicago, IL).

RESULTS AND DISCUSSION

In the present study we determined the egg production of different strains of tilapia that have tolerance to high salinity levels. The length and weight data of the different female spawners of tilapia strains that were used in the present study are shown in Table 1. F₁ female spawners of *O. mossambicus* had average length and weight of 134.78±7.72 mm and 39.78±7.86 g,

respectively. F₁ female spawners of the tilapia hybrid had a mean length of 136.2±8.66 mm and mean weight of 43.70±9.50 g. On the other hand, the F₁ female spawners of the cross between *O. mossambicus* (female) and the tilapia hybrid (male) had mean length and weight of 128.9±20.09 mm and 39.50±19.12 g, respectively. Whereas the F₁ female spawners of the cross between *O. mossambicus* (male) and the tilapia hybrid (female) had mean length of 125.30±18.24 mm and weight of 36.70±17.30 g. No significant differences in the length and weight of the female spawners among the treatment groups were observed. In the wild, tilapias reach 150-250 g at which the reproduce (Lowe-McConnell, 1958). The attainment of sexual maturity of tilapias at small sizes may reflect unstable or stressful environmental conditions (Payne, 1983). In our study, the sizes of the tilapia strains were within the range of the length and weight values for the different species of tilapia during first spawning (Coward and Bromage, 2000).

Although these strains can grow at high salinity levels (Jaspe *et al.*, 2007), the female spawners were reared in freshwater conditions. Information on the effects of salinity on fecundity and hatchability of the eggs is limited and often yielded varying results. For example, hatching rates of Nile tilapia, *O. niloticus* females were comparable at freshwater and brackishwater (12 ppt) conditions and increasing the salinity to full seawater resulted in the failure of hatching (Watanabe and Kuo, 1985). In addition, hatching and fry survival of *O. spilurus* were significantly higher in well water (4 ppt) than in seawater (40 ppt) (Al-Ahmad *et al.*, 1988). On the other hand, fry production of *O. mossambicus* was higher in brackishwater (8.9-15.2 ppt) than in freshwater (Uchida and King, 1962). These differences in the results could be attributed to the strain/species of the fish, water quality, feeding regimes and culture systems that were used (El-Sayed *et al.*, 2005). Nevertheless, the tilapia strains that we used in the study were capable of producing mature eggs in freshwater and more work is needed to find out egg production, hatching and fry survival of these saline-tolerant strains at different salinity levels.

To determine the effects of size in total fecundity of the fish, the female spawners of the tilapia strains were arbitrarily categorized into: small-, medium- and large-sized groups, representing the size range of 30-75 g. In general, higher total fecundity was observed in bigger-sized fish (Fig. 1). Among the tilapia strains, there was no significant difference on the total fecundity and size of the female spawner in the *O. mossambicus* strain (Treatment 1). Furthermore, in the tilapia hybrid (Treatment 2) and the crosses (Treatment 3 and 4), total fecundity was significantly higher in the bigger-sized (>41g) female spawners than with the smaller-sized ones (30-40 g).

The relative fecundity, on the other hand, was generally higher in the smaller-sized (30-40 g) female

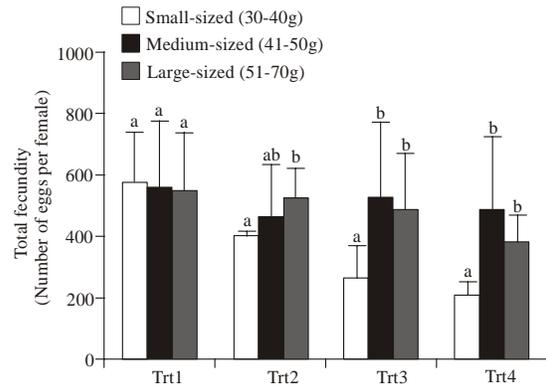


Fig. 1: Total fecundity of the different size groups of saline-tolerant tilapia strains and their crosses. Trt 1: female spawners from F₁ of *O. mossambicus* parental strain, Trt 2: female spawners from F₁ of the tilapia hybrid parental strain, Trt 3: female spawners from F₁ of the cross between *O. mossambicus* (female) x tilapia hybrid (male) and Trt 4: female spawners from F₁ of the cross between *O. mossambicus* (male) x tilapia hybrid (female). Column bars with different letters indicate significant difference at p<0.05 n = 6.

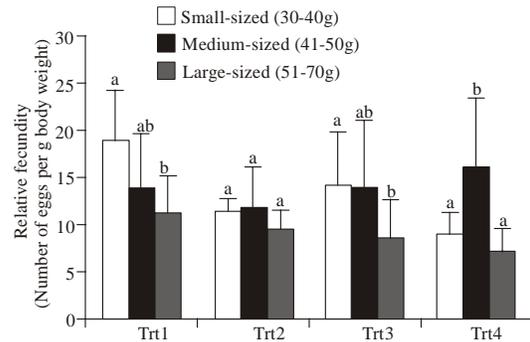


Fig. 2: Relative fecundity of the different size groups of saline-tolerant tilapia strains and their crosses. Trt 1: female spawners from F₁ of *O. mossambicus* parental strain, Trt 2: female spawners from F₁ of the tilapia hybrid parental strain, Trt 3: female spawners from F₁ of the cross between *O. mossambicus* (female) x tilapia hybrid (male) and Trt 4: female spawners from F₁ of the cross between *O. mossambicus* (male) x tilapia hybrid (female). Column bars with different letters indicate significant difference at p<0.05, n = 6.

spawners (Fig. 2). This was observed in the tilapia strains of *O. mossambicus* (Treatment 1) and the crosses (Treatment 3 and 4). On the other hand, there was no significant difference in the relative fecundity and size of the fish in the tilapia hybrid strain (Treatment 2).

The reproductive parameters of the different tilapia strains in the study are shown in Fig. 3. Highest total fecundity was observed from the female spawners of the *O. mossambicus* strain (Treatment 1), and this was

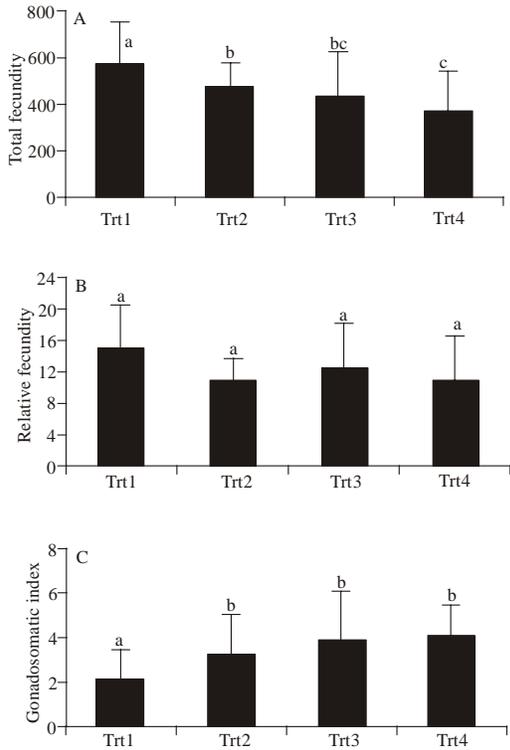


Fig. 3: Reproductive parameters: (A) Total fecundity, (B) Relative fecundity and (C) Gonadosomatic index (GSI) of the saline-tolerant tilapia strains and their crosses. Trt 1: female spawners from F₁ of *O. mossambicus* parental strain, Trt 2: female spawners from F₁ of the tilapia hybrid parental strain, Trt 3: female spawners from F₁ of the cross between *O. mossambicus* (female) x tilapia hybrid (male) and Trt 4: female spawners from F₁ of the cross between *O. mossambicus* (male) x tilapia hybrid (female). Column bars with different letters indicate significant difference at p<0.05, n = 18.

significantly different from the tilapia hybrid strain (Treatment 2) and their crosses (Treatment 3 and 4) (Fig. 3a). Relative fecundity was not significantly different among the tilapia strains studied (Fig. 3b). Gonadosomatic index (GSI) was highest in the female spawners obtained from the cross between *O. mossambicus* (male) x tilapia hybrid (female) (Treatment 4; 4.0±1.45 eggs/g BW) and lowest in *O. mossambicus* strain (Treatment 1; 2.05±1.37 eggs/g BW) (Fig. 3c). In addition, the GSI of the tilapia hybrid strain (Treatment 2) and their crosses (Treatment 3 and 4) was significantly higher than the *O. mossambicus* strain (Treatment 1).

Most *Oreochromis* species exhibit wide variations in total fecundity (Desprez *et al.*, 2008), and the results of the present study is not an exception. The total fecundity of the different tilapia strains in this study was comparable to those obtained in *O. leucostictus* (Siddiqui, 1977), *O. aureus* (Desprez *et al.*, 2008), *O. mossambicus*

Table 2: Correlation of total length (TL) and body weight (BW) and with the different reproductive parameters in saline-tolerant tilapias

	TL vs TF	TL vs RF	BW vs TF	BW vs RF
Treatment 1	-0.08 ^{ns}	-0.43*	-0.0003 ^{ns}	-0.54*
Treatment 1	0.024 ^{ns}	-0.232 ^{ns}	0.390 ^{ns}	-0.403 ^{ns}
Treatment 1	0.311 ^{ns}	-0.492*	0.317 ^{ns}	-0.527*
Treatment 1	0.218 ^{ns}	-0.320 ^{ns}	0.252 ^{ns}	-0.364 ^{ns}

ns: not significantly different at p>0.05; *: significantly different at p<0.05

(Peters, 1983) and *O. niloticus* (Babiker and Ibrahim, 1979).

The total fecundity of the tilapia strains in this study increased with maternal length and weight in general. This was in agreement with earlier studies done on other species of tilapia (Payne and Collinson, 1983; Coward and Bromage, 1999; Desprez *et al.*, 2008). Similarly, a decrease of relative fecundity with body in the different tilapia strains was consistent with another tilapia species, *O. niloticus* (Mélard, 1986).

When the different tilapia strains were grouped according to size, there was wide variation in total fecundity. This phenomenon was also observed in other tilapia species of similar size, particularly within the large sizes (Dadzie and Wangila, 1980; Coward and Bromage, 1999). Such variations could be attributed to the differential abundance of food (Coward and Bromage, 2000) and the effects of age, egg size and genetic factors (Wootton, 1979). The observed differences of these tilapia strains could be a result of the complex interaction of the above-mentioned factors.

When the reproductive parameters, such as total fecundity, relative fecundity and GSI were compared among the different high-saline tilapia strains, significant differences were observed. Previous studies have also confirmed the findings of this study. *O. spilurus* had better reproductive and spawning performance than *O. aureus* and red tilapia hybrid (Ridha, 2004). Differences in the reproductive potential are not only found between species, but also among different strains of the same species. The different strains of *O. niloticus* had varying levels of reproductive potential and spawning performance (Smitherman *et al.*, 1988; Ridha, 2008). Eguia (1996) also obtained significant differences in the seed production among four strains of the Philippine red tilapia. These discrepancies in the reproduction among tilapia species and strains could be due to the inherent genetic differences, variations in spawning compatibility among species, species-specific biological differences and environmental conditions. These factors could hold true for the different tilapia strains used in the study and additional works should be done to identify which among these factors have significant effects on egg production and other reproductive parameters.

Table 2 shows the correlation of the different variables (total length and body weight) with the

reproductive performance (total fecundity and relative fecundity) of the different tilapia strains. Both total length and body weight were positively correlated with total fecundity in the tilapia hybrid strain (Treatment 2) and their crosses (Treatment 3 and 4). However, the degree of correlation was not significantly different. No correlation was obtained in the *O. mossambicus* strain (Treatment 1). Relative fecundity was negatively correlated with total length and body weight, and the degree of correlation was significantly different in the *O. mossambicus* strain (Treatment 1) but not in the other tilapia strains (Treatment 2, 3 and 4).

As expected, total fecundity was positively correlated with total length and body weight, which was in agreement with previous studies (Fagade, 1983; Dadzie and Wangila, 1980; Duponchelle *et al.*, 1998; Anene and Okorie, 2008). On the other hand, a negative correlation between relative fecundity and the different variables was observed. However, further tests showed that the degree of correlation between these variables were not consistent among the different tilapia strains. Such inconsistencies could be related to species-specific differences and other inherent genetic factors. The number of samples utilized in the study could also be a factor that contributed to the varying results.

CONCLUSION

This study has demonstrated that the different saline-tolerant strains of tilapia are able to produce mature eggs in freshwater. Bigger-sized female spawners had higher fecundity and there is wide variation of egg production even within the same weight group. The reproductive parameters, including total fecundity, relative fecundity and GSI varied among the different strains. Both total length and body weight are positively correlated with total fecundity, but negatively correlated with relative fecundity. However, significance of the correlation varied among the tilapia strains. The results of this study are useful in establishing breeding programs for saline-tolerant strains of tilapia in order to ensure continuous supply of tilapia fry through proper broodstock management.

ACKNOWLEDGMENT

The authors gratefully acknowledge the financial support of the University of the Philippines Visayas. We are also grateful to Ms. Bessie Joy G. Elle, Mr. Jovito Ambata, Jr. and Mr. Alex Gustilo for their technical assistance during the conduct of the study.

REFERENCES

Al-Ahmad, T.A., M. Ridha and A.A. Al-Ahmad, 1988. Reproductive performance of the tilapia *Oreochromis spilurus* in sea water and brackish ground-water. *Aquaculture*, 73: 323-332.

Anene, A. and P.U. Okorie, 2008. Some aspects of the reproductive biology of *Tilapia mariae* (Boulenger 1901) in a small lake in southeastern Nigeria. *Afr. J. Biotechnol.*, 7: 2478-2482.

Babiker, M.M. and H. Ibrahim, 1979. Studies on the biology of reproduction in the cichlid *Tilapia nilotica* (L.): Gonadal maturation and fecundity. *J. Fish Biol.*, 14: 437-448.

Coward, K. and N.R. Bromage, 1999. Spawning periodicity, fecundity and egg size in *Tilapia zillii* (Gervais), substrate-spawning cichlid. *Aquaculture*, 171: 251-267.

Coward, K. and N.R. Bromage, 2000. Reproductive physiology of female tilapia broodstock. *Rev. Fish Biol. Fish.*, 10: 1-25.

Cruz, P.S., M.N. Andalencio, R.B. Bolivar and K. Fitzsimmons, 2008. Tilapia-shrimp polyculture in Negros Island, Philippines: a review. *J. World Aquac. Soc.*, 39: 713-725.

Dadzie, S. and B.C.C. Wangila, 1980. The reproductive biology, length-weight relationship and relative condition of pond-raising *Tilapia zilli* (Gervais). *J. Fish Biol.*, 17: 247-253.

Desprez, D., P. Bosc, J.F. Baroiller and C. Mélard, 2008. Variability in reproductive performance of sex-reversed tilapia *Oreochromis aureus*. *Aquaculture*, 277: 73-77.

Duponchelle, F., L. Pouyard and M. Legendre, 1998. Evidence of environmental effects on reproductive characteristics of Nile tilapia (*Oreochromis niloticus*) populations from man-made lakes of Ivory Coast. *Aquat. Liv. Resour.*, 11: 137-144.

Eguia, M.R.R., 1996. Reproductive performance of four red tilapia strains in different seed production systems. *Isr. J. Aquacult. Bamidgeh.*, 48: 10-18.

El-Sayed, A.F.M., C.R. Mansour and A.A. Ezzat, 2005. Effects of dietary lipid source on spawning performance of Nile tilapia (*Oreochromis niloticus*) broodstock reared at different water salinities. *Aquaculture*, 248: 187-196.

Fagade, S.O., 1983. The biology of *Chromidotilapia guntheri* from a small lake. *Arch. Hydrobiol.*, 17: 60-72.

Getinet, G., 2008. Effects of maternal age on fecundity, spawning interval, and egg quality of Nile tilapia, *Oreochromis niloticus* (L.). *J. World Aquac. Soc.*, 39: 671-677.

Hwang, P., C.M. Sun and S.M. Wu, 1989. Changes of plasma osmolarity, chloride concentration and gill Na⁺-K⁺-ATPase activity in tilapia (*Oreochromis mossambicus*) during seawater acclimation. *Mar. Biol.*, 100: 295-299.

Jaspe, C.J., C.M.A. Caipang and V.L. Corre, 2007. Salinity resistance of F₁ progenies from crosses between *Oreochromis mossambicus* and a tilapia hybrid, *Oreochromis spilurus* × *O. niloticus* GIFT × *O. aureus*: implications to high-saline culture. *UPV J. Nat. Sci.*, 12: 250-259.

- Kamal, A.H. and G.C. Mair, 2005. Salinity tolerance in superior genotypes of tilapia, *Oreochromis niloticus*, *Oreochromis mossambicus* and their hybrids. *Aquaculture*, 247: 189-201.
- Lowe-McConnell, R.H., 1958. Observations on the biology of *Tilapia nilotica* Linn. (Pisces: Cichlidae) in East African waters. *Revue Zool. Bot. Afr.*, 57: 129-170.
- Njiru, M., J.E. Ojuok, J.B. Okeyo-Owuor, M. Muchir, M.J. Ntiba and I.G. Cowx, 2006. Some biological aspects and life history strategies of Nile tilapia *Oreochromis niloticus* (L.) in Lake Victoria, Kenya. *Afr. J. Ecol.*, 44: 30-37.
- Payne, A.I., 1983. Estuarine and salt tolerance tilapias. *Proceeding 1st International Symposium on Tilapia in Aquaculture*. Tel Aviv University Press, Tel Aviv, Israel, pp: 534-543.
- Payne, A.I. and R.I. Collinson, 1983. A comparison of the biological characteristics of *Sarotherodon aureus* (Steindacher) with those of *S. niloticus* (L.) and other tilapia of the delta and lower Nile. *Aquaculture*, 30: 335-351.
- Peters, H.M., 1983. Fecundity, Egg Weight and Oocyte Development in Tilapias (Cichlidae, Teleostei) (ICLARM Translations 2). International Center for Living Aquatic Resources Management, Manila, Philippines.
- Ridha, M.T., 2004. Observations on the reproductive performance of three mouth-brooding tilapia species in low-salinity underground water. *Aquac. Res.*, 35: 1031-1038.
- Ridha, M.T., 2008. Comparative study on seed production in two strains of the Nile tilapia *Oreochromis niloticus*. *Eur. J. Sci. Res.*, 19: 752-757.
- Ridha, M.T. and E.M. Cruz, 2000. Effect of light intensity and photoperiod on the Nile tilapia *Oreochromis niloticus* L. seed production. *Aquac. Res.*, 31: 609-617.
- Ridha, M.T. and E.M. Cruz, 1998. Observations on the seed production of the tilapia *Oreochromis spilurus* (Günther) under different spawning conditions and with different sex ratios. *Asian Fish. Sci.*, 10: 199-208.
- Siddiqui, A.Q., 1977. Reproductive biology, length-weight relationship and relative condition of *Tilapia leucostica* (Trewavas) in Lake Naivasha, Kenya. *J. Fish Biol.*, 10: 251-260.
- Siddiqui, A.Q., A.H. Al-Harbi and Y.S. Al-Hafedh, 1997. Effects of food supply on size at first maturity, fecundity and growth of hybrid tilapia, *Oreochromis niloticus* (L.) × *Oreochromis aureus* (Steindachner), in outdoor concrete tanks in Saudi Arabia. *Aquacult. Res.*, 28: 341-349.
- Smitherman, R.O., A.A. Khater, N.I. Casell and R.A. Dunham, 1988. Reproductive performance of three strains of *Oreochromis niloticus*. *Aquaculture*, 7: 29-37.
- Stickney, R.R., 1986. Tilapia tolerance in saline waters: a review. *Prog. Fish Culturist*, 48: 61-67.
- Tendencia, E.A., M.R. de la Peña, A.C. Fermin, G.D. Lio-Po, C.H. Choresca Jr. and Y. Inui, 2004. Antibacterial activity of *Tilapia hornorum* against *Vibrio harveyi*. *Aquaculture*, 232: 145-152.
- Tendencia, E.A., M.R. de la Peña and C.H. Choresca, 2005. Efficiency of *Chlorella* sp. and *Tilapia hornorum* in controlling the growth of luminous bacteria in a simulated shrimp culture environment. *Aquaculture*, 249: 55-62.
- Uchida, R.N. and J.E. King, 1962. Tank culture of tilapia. *US Fish Wildl. Serv. Fish. Bull.*, 199: 21-47.
- Watanabe, W.O. and C.M. Kuo, 1985. Observations on the reproductive performance of Nile tilapia (*Oreochromis niloticus*) in laboratory aquaria at various salinities. *Aquaculture*, 49: 315-323.
- Wootton, R.J., 1979. Energy Costs of Egg Production and Environmental Determinants of Fecundity in Teleost Fishes. In: Miller, P.J. (Ed.), *Fish Phenology: Anabolic Adaptiveness in Teleosts* (Symposium of the Zoological Society of London No. 44), Academic Press, London, UK, pp: 133-159.