# EFFECTS OF FERTILIZATON RATES ON GROWTH PERFORMANCE OF RED TILAPIA AT DIFFERENT SALINITIES

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## Abstract

An experiment was conducted at the Asian Institute of Technology, Thailand, to investigate effects of fertilization rates and salinity levels on the growth of sex-reversed, Thai red tilapia (*Oreochromis* sp.). The experiment was designed to test two fertilization rates (28 kg N and 7 kg P $ha^{-1}$ $week^{-1}$, N: P=4:1; and 14 kg N and 7 kg P $ha^{-1}$ $week^{-1}$, N: P=2:1) and three salinity levels (10, 20, and 30 ppt) in brackishwater. An additional treatment using optimized fertilization rates (28 kg N and 7 kg P $ha^{-1}$ $week^{-1}$, N: P=4:1) in freshwater ponds served as control. Red tilapia fingerlings (20.2-23.7 g size) were stocked at 2.4 fish $m^{-2}$ in 5-$m^2$ cement tanks with soil bottoms. These were cultured for 160 days.

Growth performance of red tilapia was better in brackishwater than in freshwater. Growth of red tilapia in brackishwater was inversely related to the salinity levels ($r= -0.63$, $P < 0.05$), decreasing significantly with increasing salinity. For a given salinity level, there was no significant difference in size at harvest for the two fertilization regimes ($P > 0.05$). Best growth performance was achieved in the treatment with N:P ratio of 4:1 at 10 ppt salinity.

## Introduction

Many tilapia species are euryhaline and can grow in saline water after proper acclimation (Suresh and Lin, 1992). Varieties of red tilapia have been successfully cultured in saline waters (Watanabe, 1991). However, most of those tilapia culture trials were conducted in intensive systems with pelleted feeds, requiring frequent water exchanges or cages. Compared to the voluminous literature available for semi-intensive culture of tilapia in freshwater ponds, literature on semi-intensive culture in saline ponds is almost non-existent. The species composition, feeding and nutritional value of phytoplankton for tilapia growth in freshwater are relatively well understood, notably in work by Hepher and Pruginin (1982), Moriarty and

Moriarty (1973), Bowen (1982) and recently Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP) (Egna and Boyd, 1997). The PD/A CRSP project conducted a brief experiment on Nile tilapia grow-out in fertilized brackishwater ponds in the Philippines in early 1980s (Woessner *et al*., 1991). In that experiment, fish production was extremely low, resulting from high mortality due to uncontrolled high salinity. We are assuming that fertilization rates for brackishwater ponds are similar to those for freshwater ponds. Common PD/A CRSP fertilization guidelines are 28 kg nitrogen (N) and 7 kg phosphorus (P) $ha^{-1}$ $week^{-1}$, giving a N: P ratio of 4:1 (Knud-Hansen *et al*., 1991).

During the last few years, there has been a strong desire to culture tilapia in brackishwater ponds in Southeast Asia as well as Central/South America (Green, 1997). The major reason for this need is that there are a large number of shrimp ponds available, either resulting from failure in shrimp farming or desires to diversify shrimp culture. Tilapias appear to be the most appropriate choice for such a culture system, because there are few domesticated finfish species that feed on low-cost natural foods like detritus and plankton. This interest in brackishwater culture is particularly strong in Thailand and Vietnam where shrimp culture is now commonly reduced to one crop per year, leaving the ponds empty for half a year. Tilapia culture is also attractive to shrimp farmers as a by-product to utilize abundant phytoplankton in either shrimp ponds or their effluents. Thai strain red tilapia (*Oreochromis* sp.) is becoming more popular in Thailand, and there is a great potential to culture this species in brackishwater ponds. The purpose of this study was to investigate effects of fertilization rates and salinity levels on the growth of sex-reversed, Thai red tilapia (*Oreochromis* sp.) in brackishwater.

## Materials and methods

This experiment was carried out at the Asian Institute of Technology (AIT), Thailand, from June-November 2000. The experiment was conducted in a randomized complete block design with a 2x3 factorial arrangement to test effects of two fertilization regimes (28 kg N and 7 kg P $ha^{-1}$ $week^{-1}$, N: P=4:1; and 14 kg N and 7 kg P $ha^{-1}$ $week^{-1}$, N: P=2:1) and three salinity levels (10, 20, and 30 ppt) on the growth of Thai red tilapia. There were six combinations (treatments), and an additional treatment using PD/A CRSP standard fertilization regime (28 kg N and 7 kg P $ha^{-1}$ $week^{-1}$, N: P=4:1) in freshwater (0 ppt) serving as control. Three replicates were used per treatment. The experiment was conducted in twenty-one 5-$m^2$ (2x2.5 m) cement tanks filled with 10-cm of soil on the bottom. The tanks were grouped into three blocks, and treatments were allocated randomly to tanks in each block.

Thai strain red tilapia was used in the experiment. Sex-reversed all-male Thai red tilapia fingerlings (20.2-23.7 g size) were purchased from a local hatchery, and acclimated to appropriate salinity levels in acclimation tanks by raising salinity level 5 ppt every two days until the target salinity was reached. The acclimated Thai red tilapia fingerlings were stocked at 2.4 fish $m^{-2}$ in all experimental tanks on 8 June 2000. During the experiment, 50% of the initial tilapia stock was seined, counted and weighed en-masse biweekly for each tank. All fish were harvested on 15 November 2000 after 160 days of culture. Daily weight gain (g $fish^{-1}d^{-1}$), yield (kg $pond^{-1}$) and extrapolated yield (kg $ha^{-1}$ $year^{-1}$) were calculated.

All tanks were fertilized weekly with urea and triple super phosphate (TSP) to achieve the treatment dosage. Initial pond fertilization took place one week prior to fish stocking. Sodium bicarbonate was applied at 250 kg/ha on the third week. Salinity was regulated by trucking hypersaline water (150 ppt) to AIT and diluting to the appropriate concentrations. Salinity levels in all tanks were monitored weekly. Water depth in all tanks was maintained at 1 m throughout the experiment by adding water of appropriate salinity levels weekly to replace evaporation and seepage losses. All tanks were aerated for 24 hours daily using one airstone in each tank.

Water samples integrated from the entire water column were taken biweekly near the center of each tank at approximately 0900 h for analysis of pH, alkalinity, total ammonium nitrogen (TAN), nitrite nitrogen, nitrate nitrogen, total Kjeldahl nitrogen (TKN), soluble reactive phosphorus (SRP), total phosphorus (TP), chlorophyll *a*, total suspended solids (TSS), and total volatile solids (TVS) (APHA *et al*., 1985; Parsons *et al*., 1984; Egna *et al*., 1987). Secchi disk visibility, temperature and dissolved oxygen (DO) were also measured at the time of collecting water samples with a Secchi disk and YSI model 54 oxygen meter (Yellow Springs Instruments, Yellow Springs, Ohio, USA), respectively. Diel measurements for temperature, DO and pH were conducted in each pond at 0600, 1000, 1400, 1600, 1800, and 0600 h once a month.

Data were analyzed statistically using analysis of variance and linear regression (Steele and Torrie, 1980) with SPSS (version 7.0) statistical software package (SPSS Inc., Chicago, USA). Differences were considered significant at an alpha of 0.05. Statistical analyses for survival rates (%) were performed on data after arcsine transformation. Mean values of survival rates in this text are listed in normal scale followed by their confidence limits. All other means are given with ±1 standard error (S.E.).

## Results

There was no mortality of red tilapia in any treatment. Red tilapia grew fast in the first two months and then growth declined towards the end of the experiment period (Figs. 1 and 2). Growth performance of red tilapia (Table 1) was inversely related to salinity levels ($r = -0.63$, $P < 0.05$), and size at harvest decreased with increased salinity (Fig. 3). For a given salinity level, there was no significant difference in size at harvest for the two fertilization regimes ($P > 0.05$, Table 1 and Fig. 3). All growth performance parameters were best in the treatment with high N:P ratio at 10 ppt salinity, and were significantly better than those in the treatment with low N:P ratio at 30 ppt salinity and those in the freshwater treatment ($P < 0.05$), but were not significantly different from other brackishwater treatments ($P > 0.05$, Table 1). Growth performance in freshwater was lowest and significantly lower than that in the treatments with high N:P ratio at 10 and 20 ppt salinity and with low N:P ratio at 10 ppt salinity. Growth of red tilapia in brackishwater was 22-72% faster than that in freshwater. There was no significant interaction between N:P ratio and salinity levels on the growth of red tilapia ($P > 0.05$).

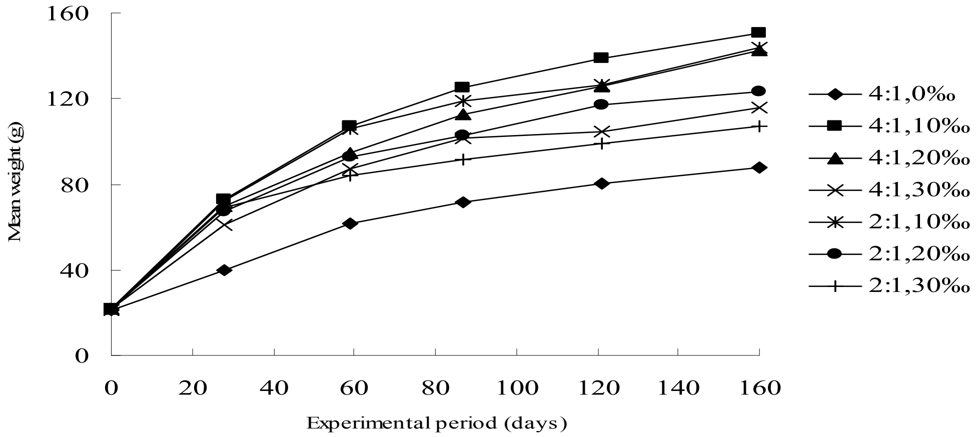


Fig. 1. Mean weight of Thai red tilapia in all treatments over the 160-day experimental period.

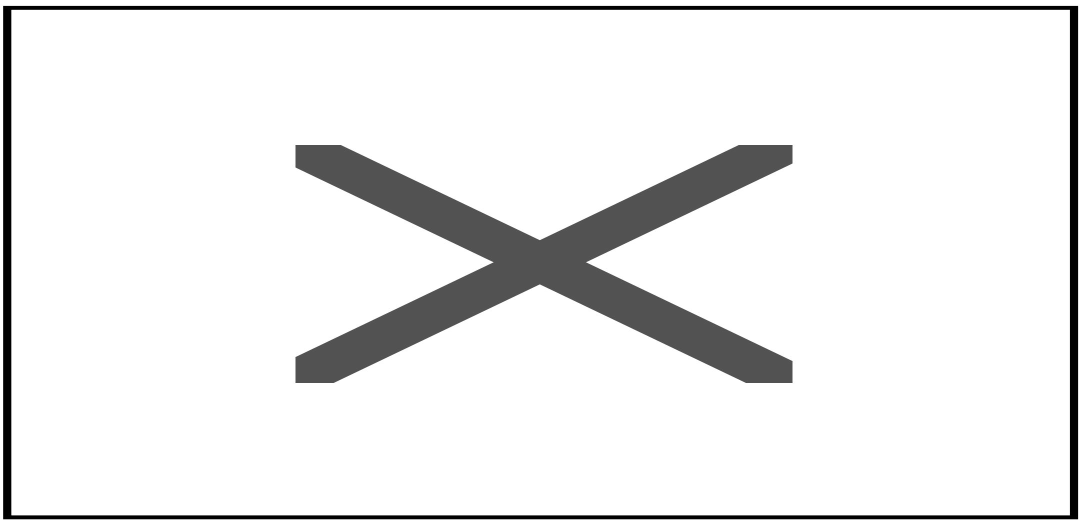

Fig. 2. Daily weight gain of Thai red tilapia in all treatments over the 160-day experimental period.

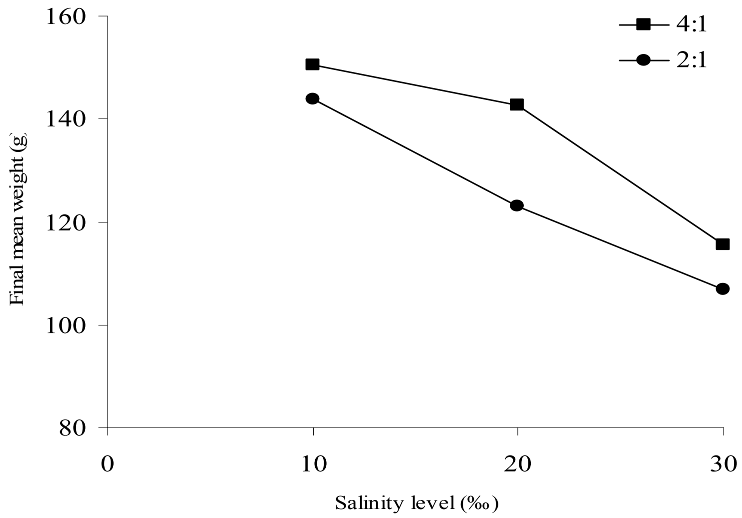


Fig. 3. Comparison of final mean weight of Thai red tilapia cultured at different salinity levels under the both low and high fertilization rates after the 160-day experiment period.

Table 1. Performance values (mean ± SE) of Thai red tilapia in cement tanks at different fertilization regimes and salinity levels at stocking and harvest (160 d later). Data with superscripts showed significant differences among treatments, and treatments with the same superscript are not significantly different.

| Parameters | Salinity and Fertilization Rate | | | | | | |
|---|---|---|---|---|---|---|---|
| | N:P=4:1 | | | | N:P=2:1 | | |
| | 0‰ | 10‰ | 20‰ | 30‰ | 10‰ | 20‰ | 30‰ |
| **Stocking** | | | | | | | |
| Density (fish $m^{-2}$) | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 | 2.4 |
| Total number (fish $tank^{-1}$) | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| Mean weight (g $fish^{-1}$) | 21.4±0.3 | 22.0±0.4 | 21.6±0.3 | 21.9±0.9 | 21.5±0.6 | 22.0±0.2 | 22.1±1.0 |
| Total weight (kg $tank^{-1}$) | 0.26±0.00 | 0.26±0.00 | 0.26±0.00 | 0.26±0.01 | 0.26±0.01 | 0.26±0.00 | 0.26±0.01 |
| **Harvest** | | | | | | | |
| Total number (fish $tank^{-1}$) | 12±0 | 12±0 | 12±0 | 12±0 | 12±0 | 12±0 | 12±0 |
| Mean weight (g $fish^{-1}$) | 87.5±11.7 [a] | 150.5±9.2 [c] | 142.8±17.0 [bc] | 115.6±11.0 [abc] | 144.0±14.3 [bc] | 123.1±6.1 [abc] | 106.8±10.0 [ab] |
| Total weight (kg $tank^{-1}$) | 1.05±0.14 [a] | 1.81±0.11 [c] | 1.71±0.20 [bc] | 1.39±0.13 [abc] | 1.73±0.17 [bc] | 1.48±0.07 [abc] | 1.28±0.12 [ab] |
| Survival Rate (%) | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Daily weight gain (g $fish^{-1}$ $d^{-1}$) | 0.41±0.07 [a] | 0.80±0.06 [c] | 0.76±0.11 [bc] | 0.59±0.06 [abc] | 0.77±0.09 [bc] | 0.63±0.04 [abc] | 0.53±0.07 [ab] |
| Total weight gain (kg $tank^{-1}$) | 0.79±0.14 [a] | 1.54±0.11 [c] | 1.45±0.21 [bc] | 1.12±0.12 [abc] | 1.47±0.17 [bc] | 1.21±0.07 [abc] | 1.02±0.13 [ab] |
| Net yield (t $ha^{-1}$ $year^{-1}$) | 3.62±0.64 [a] | 7.04±0.48 [c] | 6.64±0.95 [bc] | 5.13±0.56 [abc] | 6.71±0.76 [bc] | 5.53±0.33 [abc] | 4.64±0.58 [ab] |
| Gross yield (t $ha^{-1}$ $year^{-1}$) | 4.79±0.64 [a] | 8.24±0.50 [c] | 7.82±0.93 [bc] | 6.33±0.60 [abc] | 7.88±0.78 [bc] | 6.74±0.34 [abc] | 5.85±0.54 [ab] |

Mean values of water quality parameters measured throughout the experimental period are summarized in Table 2. DO concentrations at dawn were above 4 mg $L^{-1}$ on average. Water temperature and pH values ranged from 28.1 to 32.7 C and 5.7 to 11.1, respectively; both did not differ among treatments. Alkalinity was generally low in all treatments throughout the experimental period except for an increase after applying sodium bicarbonate in the third week. Alkalinity of the freshwater treatment was significantly higher than in the brackishwater treatments ($P < 0.05$), among which there were no significant differences. Concentrations of TKN, nitrite-N and nitrate-N were higher in the treatments with high N:P ratio than in the treatments with low N:P ratio, and the highest values were obtained in the treatment with high N:P ratio at 10 ppt salinity ($P < 0.05$), while TAN concentration were significantly higher in the treatment with high N:P ratio at 30 ppt salinity than other treatments ($P < 0.05$), among which there were no significant differences ($P > 0.05$). However, concentrations of both TP and SRP were not significantly different in any treatment ($P > 0.05$). Chlorophyll *a* concentrations fluctuated throughout the experimental period without significant differences among treatments ($P > 0.05$). N:P ratios increased significantly with increasing salinity levels ($P < 0.05$, Fig. 4) but did not result to significant differences in both TSS and TVS ($P > 0.05$).

## Discussion

Thai red tilapia grew faster in brackishwater than in freshwater in this experiment, which is consistent with the results obtained by Hoa (1996). Similar results were also reported in monosex Florida red tilapia (Watanabe *et al*., 1988a, 1993), *O. mossambicus* (Canagaratnam, 1966; Jurss *et al*., 1984; Villegas, 1990), *O. mossambicus* x *O. hornorum* hybrid (Garcia and Sedjro, 1987 cited by Watanabe *et al*., 1993), mixed-sex Taiwanese red tilapia (*O. mossambicus* x *O. niloticus* hybrid) (Liao and Chang, 1983), and $F_1$ hybrid of *O. mossambicus* x *O. niloticus* (Villegas, 1990). The better growth performance in saline water might be attributed to higher osmoregulation energy costs in freshwater than in brackishwater or seawater found in *O. mossambicus* x *O. hornorum* hybrid (Febry and Lutz, 1987), suppressed territorial aggression by salinity (Watanabe *et al*., 1988b), and inhibitory effects of aggressive behavior which varied among different salinities (Liao and Chang, 1983). In contrast, all-male Taiwanese red tilapia exhibited faster growth in freshwater than in saltwater (Liao and Chang, 1983), and similar results were found in *O. niloticus* (Villegas, 1990).

Results of studies on effects of salinity on fish growth are controversial. Under saline water conditions, growth of Thai red tilapia decreased with increased salinity levels from 10 to 30 ppt in both low and high fertilization rates in the present experiment. This indicates that the growth of Thai red tilapia may reach a peak at the salinity levels of around 10 ppt, which is in accordance with the results (12 ppt) for the red tilapia from UK (Payne *et al*., 1988). These results support the common assumption that growth of euryhaline teleosts is increased at salinities near iso-osmotic, since osmoregulation costs are minimal under these conditions. Febry and Lutz (1987) found in *O. mossambicus* x *O. hornorum* hybrids that osmoregulation costs were lowest in iso-osmotic seawater (12 ppt). However, growth at salinities near iso-

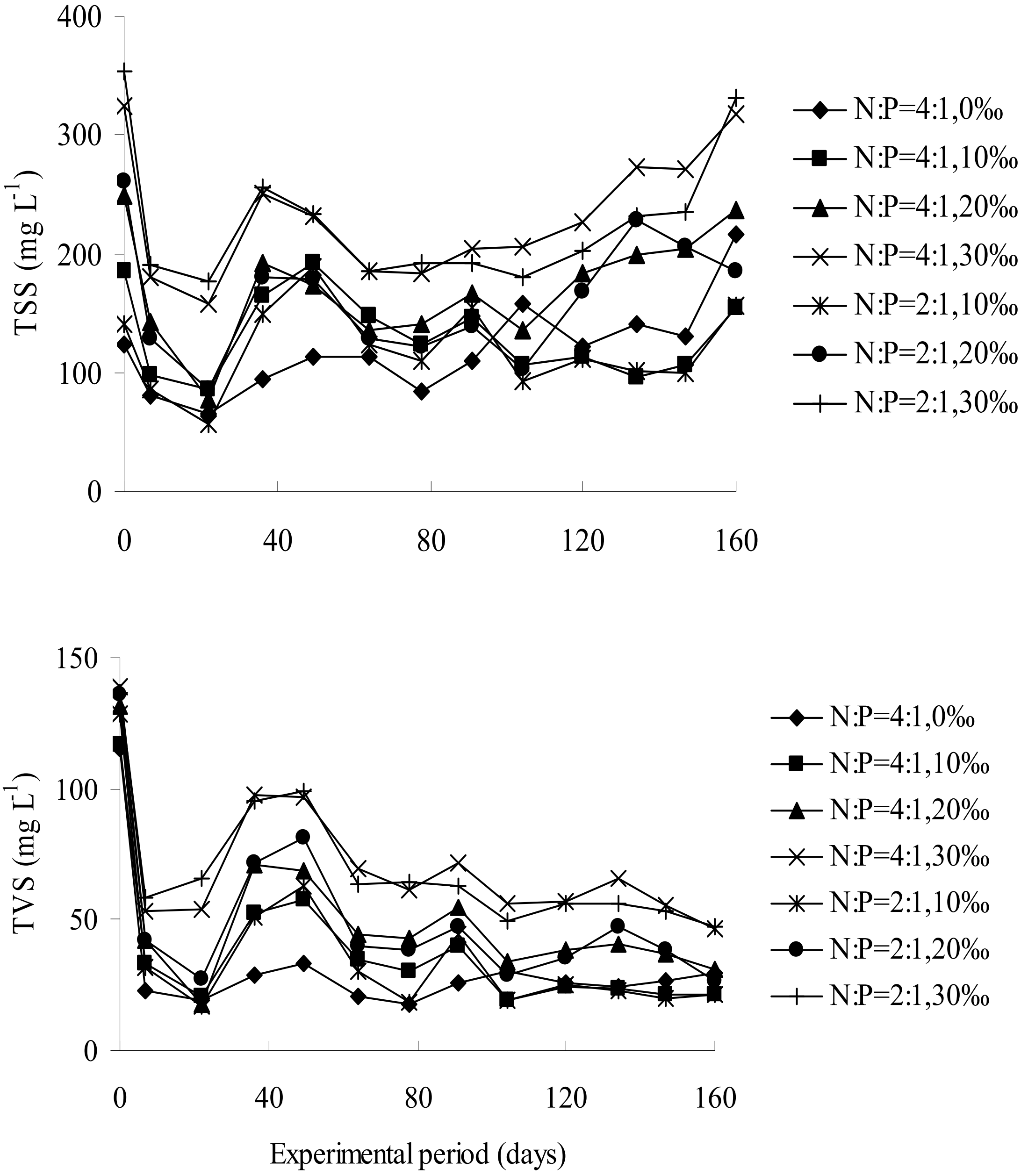


Fig. 4. Fluctuations of TSS and TVS (0900 h) in all treatments over the 160-day experimental period.

Table 2. Mean (± SE) values of water quality parameters measured throughout the experiment. Significant differences in data notes as in Table 1.

| Parameters | Salinity and Fertilization Rate | | | | | | |
|---|---|---|---|---|---|---|---|
| | N:P=4:1 | | | | N:P=2:1 | | |
| | 0‰ | 10‰ | 20‰ | 30‰ | 10‰ | 20‰ | 30‰ |
| DO at dawn (mg $L^{-1}$) | 5.40±0.26 | 5.74±0.17 | 5.04±0.19 | 4.77±0.16 | 5.63±0.20 | 5.07±0.20 | 5.00±0.17 |
| Temperature (C) | 28.2-32.7 | 28.1-32.7 | 28.2-32.7 | 28.2-32.7 | 28.2-32.7 | 28.3-32.7 | 28.1-32.7 |
| pH | 7.1-11.1 | 6.4-10.2 | 6.3-10.0 | 6.1-9.6 | 5.7-11.0 | 6.7-10.2 | 6.4-9.8 |
| Alkalinity (mg $L^{-1}$ as $CaCO_3$) | 46.5±1.4 [a] | 27.6±2.9 [b] | 29.7±1.6 [b] | 22.9±1.2 [b] | 29.3±2.7 [b] | 27.8±2.9 [b] | 27.8±6.8 [b] |
| TKN (mg $L^{-1}$) | 1.90±0.17 [ab] | 2.91±0.34 [c] | 2.60±0.32 [bc] | 2.05±0.25 [ab] | 1.41±0.18 [a] | 1.75±0.43 [a] | 1.24±0.08 [a] |
| TAN (mg $L^{-1}$) | 0.02±0.00 [a] | 0.05±0.00 [a] | 0.05±0.00 [a] | 0.09±0.01 [b] | 0.04±0.01 [a] | 0.04±0.01 [a] | 0.05±0.02 [a] |
| Nitrite-N (mg $L^{-1}$) | 0.38±0.03 [abc] | 0.44±0.01 [c] | 0.42±0.02 [bc] | 0.39±0.04 [abc] | 0.35±0.03 [ab] | 0.31±0.02 [a] | 0.31±0.04 [a] |
| Nitrate-N (mg $L^{-1}$) | 0.43±0.06 [ab] | 0.87±0.03 [d] | 0.85±0.10 [d] | 0.70±0.08 [cd] | 0.36±0.04 [a] | 0.63±0.07 [bc] | 0.56±0.02 [bc] |
| TP (mg $L^{-1}$) | 0.83±0.13 | 0.52±0.07 | 0.56±0.02 | 0.41±0.07 | 0.47±0.05 | 0.53±0.09 | 0.61±0.17 |
| SRP (mg $L^{-1}$) | 0.56±0.16 | 0.30±0.07 | 0.35±0.03 | 0.20±0.06 | 0.26±0.05 | 0.30±0.08 | 0.44±0.19 |
| Chlorophyll *a* (mg $m^{-3}$) | 62±15.0 | 53±3.4 | 57±7.5 | 72±1.4 | 58±3.7 | 68±9.0 | 69±7.1 |
| TSS (mg $L^{-1}$) | 119±8.6 [a] | 132±4.0 [a] | 172±6.9 [b] | 232±9.1 [c] | 121±6.4 [a] | 163±4.7 [b] | 228±15.6 [c] |
| TVS (mg $L^{-1}$) | 32±3.4 [a] | 38±1.3 [a] | 50±4.0 [b] | 71±2.8 [c] | 38±3.0 [a] | 51±2.8 [b] | 70±4.4 [c] |

osmotic was found to be lower than that at higher salinities in Florida red tilapia (Watanabe *et al*., 1988a) and $F_1$ hybrid of *O. mossambicus* x *O. niloticus* (Villegas, 1990). Febry and Lutz (1987) and Watanabe *et al*. (1988b) proposed that non-osmoregulatory factors such as aggression might also influence the growth performance of tilapia cultured in saline water. Territorial aggression might account for one-third to one-half of the active metabolic rate in teleosts during intense contesting (Brett and Groves, 1979). Watanabe *et al*. (1988a) attributed the increased growth they found with increasing salinity for Florida red tilapia to increased food consumption and lowered food conversion ratio in high salinity.

The fertilization regime with high N:P ratio (28 kg N and 7 kg P $ha^{-1}$ $week^{-1}$) resulted in good growth performance of Thai red tilapia at all tested salinity levels. The results suggested that the optimized fertilization regime in freshwater can be applied in brackishwater. However, the simple partial budget analysis based on the market prices in Thailand indicated that net return from the fertilization regime with low N:P ratio (14 kg N and 7 kg P $ha^{-1}$ $week^{-1}$) was higher than that from high N:P ratio (28 kg N and 7 kg P $ha^{-1}$ $week^{-1}$). The fertilization regime in brackishwater ponds may be further fine-tuned based on the local conditions.

One surprising result of this experiment was that the growth of Thai red tilapia in freshwater (0.42 g $d^{-1}$) was far below the growth rate of sex-reversed normal *Oreochromis niloiticus* (averaging 1 g/d; Diana, 1997), while growth in brackishwater was also poor but approached the normal level. It is generally observed that there is poor growth of tilapias in cement tanks. The same source of Thai red tilapia grew very well (1.17 g $d^{-1}$) at a density of 62.5 fish $m^{-3}$ in cages suspended in an earthen ponds (Yi *et al*., 2002). However, it would be useful to compare the two tilapia strains for growth characteristics under different salinity conditions to better understand both economic and biological production.

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