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The effect of Artificial Vegetation Density on Growth and Growth related Parameters of Nile Tilapia, *Oreochromis niloticus* (L.) Fry

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Abstract

A growth response study was carried out to evaluate the influence of artificially submerged macrophytes on growth performance and supplemental feed utilization of Nile tilapia, *Oreochromis niloticus* (L.) fry under aquarium conditions. In glass aquarium (80 x 50 x 50 cm) filled with 140 litres of well-aerated tap water (25 to 28 ^{o}C), leafless stems of phragmites plant (0.7 m long and 0.5 cm diameter) were used at densities of 0, 25, 50, 75, 100 and 125 stems/m^2. The final fish weight, weight gain and specific growth rate (SGR) decreased significantly with the increase in plant density ($P<0.05$). The lowest fish growth was obtained at densities over 75 stems/ m^2. The higher feed intake was recorded at control, while the lowest one was obtained at densities of 75-125 stems/m^2 ($P<0.05$). In contrast, feed conversion ratio (FCR) was only higher at the density of 125 stems/m^2 ($P<0.05$). The protein efficiency ratio (PER), protein productive value (PPV) and protein growth rate (PGR) declined significantly at the density of 125 stems/m^2 ($P<0.05$). Contents of moisture and crude protein in whole fish body increased slightly with the increase in plant density ($P>0.05$). The total lipid content was only decreased, while ash content increased significantly at plant density of 125 stems/m^2. It could be recommended that submerged macrophytes, used as fish refuges from predators or for periphyton production, should be at low or moderate density, however, dense vegetation reduces significantly fish growth and feed utilization.

Key Words: Aquatic vegetation, Nile tilapia, growth, feed utilization, feed conversion ratio, protein efficiency ratio, protein growth rate.

Introduction

Aquatic macrophyte communities, especially emergent and submerged plants are of great importance to the dynamics of aquatic ecosystems, affecting both biotic and abiotic processes (Carpenter and Lodge, 1986; Jeppesen *et al*., 1998). In aquatic systems, vegetation distribution patterns produce considerable structural variation in both pelagic and littoral zone (Dionne and Folt, 1991; Schriver *et al*., 1995), and vegetation could provide refuge for prey communities by hindering predator foraging activity (Persson, 1993; Beklioglu and Moss, 1996; Manatunge *et al*., 2000). Although aquatic plants influence both fish distribution and abundance by creating structurally complex habitats, foraging success of fish generally declines as plant density increases (Savino and Stein, 1982; Wiley *et al*., 1984; Spitzer *et al*., 2000).

Despite the obvious importance of the refuge potential of macrophytes for prey communities in natural aquatic systems and semi-intensive fishponds, macrophytes could be used as artificial substrate to enhance periphyton production for tilapia food in aquaculture ponds (Keshavanath *et al*., 2004). Spitzer *et al*. (2000) reported that the efficiency of visual predators may often be affected by habitat complexity. However, the increase in habitat complexity may lead to an increase in search and/or pursuit times, while decreasing habitat complexity may reduce search and/or pursuit times and results in elevated feeding success.

Nile tilapia, *Oreochromis niloticus* (L.) is one of the most common species in natural water, in Egypt, including the River Nile, its tributaries and many lakes. However, the natural habitats of Nile tilapia are extremely occupied by many aquatic plants that threat the natural habitat. Creating complex habitat, aquatic vegetation, may have an effect on biological interaction. Nile tilapia is also widely cultured in earthen ponds. Sometimes these earthen ponds may be occupied by aquatic vegetation, which influences the growth of this fish. Few studies have examined how vegetation density influences the growth performance and supplemental feed utilization, when Nile tilapia was reared in vegetated area with submerged macrophytes. Therefore, habitats having different stem densities could be simulated in an indoor laboratory to investigate the influence of aquatic vegetation density on growth performance of Nile tilapia.

Materials and Methods

The Experimental Design and Fish Culture

This experiment was conducted in 140-L glass aquaria (80 x 50 x 50 cm) filled with well-aerated tap

water supplied from a storage fiberglass tank. The leafless stem of phragmites plants (0.7 m long and 0.5 cm diameter) was used as described by Manatunge *et al*. (2000). These bars were attached to a wire at the top and the bottom, extended to the bottom of the aquarium at plant densities of 0, 10, 20, 30, 40 and 50 stems/aquarium (i.e. 0, 25, 50, 75, 100 and 125 stems/m^2). Each plant density was represented by three aquaria.

All-male hormone-treated monosex fry of Nile tilapia, *Oreochromis niloticus* (L.) (1.0-1.5 g) were obtained from Abbassa fish hatchery, Abo-Hammad, Sharqia, Egypt. Fish were held in an indoor tank for 2 weeks for acclimation to the laboratory conditions. The fish were randomly distributed in each aquarium at a rate of 20 fish per aquarium. Each aquarium was aerated with air pumps. The water temperature ranged from 25 ^oC to 28 ^oC. Half of water was siphoned daily from each aquarium to remove excreta and replaced with an equal volume of well-aerated tap water. Dead fish were removed and recorded daily.

A semi-moist basal diet contained 91.8% dry matter, 25.4% crude protein, 6.4% total lipids, 6.6% ash, and 438.4 kcal/100 g of gross energy were given to fish for satiation twice daily at 9:00 and 14:00 for 14 weeks, five days a week. Fish in each aquarium was weighed biweekly.

The whole fish body from each treatment was chemically analyzed according to the standard methods of AOAC (1990) for dry matter, crude protein, total lipids and ash. Moisture content was estimated by heating samples in an oven at 85 ^oC until constant weight, and the calculated difference between initial weight and the weight after drying was recorded as moisture content. Nitrogen content was measured using a microkjeldahl apparatus and crude protein was estimated by multiplying total nitrogen content by 6.25. Total lipids content was determined by ether extraction for 16 h, and ash was determined by combusting samples in a muffle furnace at 550 ^oC for 6 h.

Growth performance was determined and feed utilization was calculated as described by Sveier *et al*. (2000) using the equations below:

Weight gain = $W_2 - W_1$

Specific growth rate (SGR) = $100 (\ln W_2 - \ln W_1) / T$

where W_1 and W_2 are the initial and final fish weight (g), respectively, and T is the number of days in the feeding period.

Feed conversion ratio = feed intake / weight gain (FCR)

Protein efficiency ratio = weight gain / protein intake (PER)

Protein productive value (PPV %) = 100 x protein gain in fish / protein intake in feed

Protein growth rate (PGR %/day) = $100 (\ln P_2 - \ln P_1) / T$

where P_1 and P_2 are the initial and final protein content in fish, respectively, and T is the number of days in the feeding period.

Data Analysis

The data obtained were subjected to Kolmogrov-Smirnov and Cochran's tests for normality and homogeneity of variance, respectively. The data were homogenous and showed normal distribution. So, one-way ANOVA was used to determine significant differences. Mean separations were determined using Tukey's test at the 5% probability level. Correlation analyses were performed by fitting the data into a curvilinear pattern for selecting the model giving the best fit. The software SPSS, version 10 (SPSS, Richmond, USA) was used as described by Dytham (1999).

Results

Figure 1 showed that the final fish weight decreased significantly with the increase in plant density ($P<0.05$). The weight gain and SGR declined significantly with increasing plant density in aquarium over 75 stems/m^2 ($P<0.05$; Table 1). The lowest final weight and weight gain were obtained at the density of 125 stem/m^2 (8.1 and 6.8 g/fish, respectively). Figure 2 showed the negative correlations of final fish weight or weight gain with vegetation density (r^2 = - 0.9845 and - 0.9894, respectively). SGR was significantly lower at densities of 75-125 stem/m^2 (2.193 - 1.946 %/day, respectively). Survival rate did not significantly vary with the increase in plant density under aquarium condition ($P>0.05$).

Feed intake was significantly reduced, while FCR increased with the increase of plant density over 50 stems/m^2 ($P<0.05$; Table 2). The highest feed intake was recorded at control (15.1 g feed/fish), while the lowest one was obtained at the density of 125 stems/m^2 (10.7 g feed/fish). FCR was only higher at density of 125 stems/m^2 (1.57; $P<0.05$), while it was not significantly differed at other plant densities ($P>0.05$). PER increased significantly with the increase of plant density in aquarium at 75 stems/m^2 ($P<0.05$; Table 2), and decreased again at densities of 100 and 125 stems/m^2 (2.872 and 2.739, respectively; $P<0.05$). On the other hand, PPV and PGR were significantly reduced with the increase in plant density in aquarium where the lowest values were obtained at the density of 125 stems/m^2 (36.57% and 1.908 %/day, respectively; $P<0.05$; Table 2). There were negative correlations between feed intake, PER

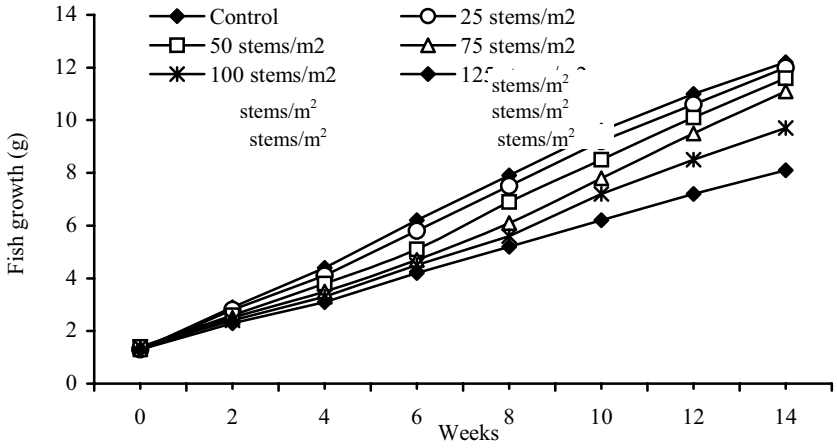

Figure 1. Changes in live body weight (g/fish) of Nile tilapia reared in glass aquaria containing different levels of plant stems.

Table 1. Growth performance (mean ± SE) of Nile tilapia reared in glass aquaria containing different levels of plant stems

Treats	Initial weight (g/fish)	Final weight (g/fish)	Weight gain (g/fish)	SGR (%/day)	Survival rate (%)
Control (0 stems/m^2)	1.3± 0.03^a	12.2± 0.35^a	10.9± 0.35^a	2.382± 0.043^a	97.8± 2.2^a
25 stems/m^2	1.4 ± 0.03^a	12.1± 0.29^a	10.7± 0.26^a	2.294± 0.075^{ab}	97.8± 2.2^a
50 stems/m^2	1.4 ± 0.03^a	11.6 ± 0.24^a	10.2 ± 0.26^a	2.250± 0.038^{ab}	93.4 ± 3.8^a
75 stems/m^2	1.4 ± 0.03^a	11.0± 0.32^a	9.6± 0.32^a	2.193± 0.036^b	93.4 ± 3.8^a
100 stems/m^2	1.3± 0.03^a	9.7± 0.12^b	8.4 ± 0.09^b	2.138± 0.017^b	93.4 ± 3.8^a
125 stems/m^2	1.3± 0.03^a	8.1± 0.18^c	6.8 ± 0.21^c	1.946± 0.049^c	91.2± 2.2^a

Means with the same letter in the same column are not significantly different at P<0.05.

Table 2. Feed intake, feed conversion ratio (FCR), protein efficiency ratio (PER) and protein growth rate (PGR) of Nile tilapia reared in glass aquaria containing different levels of plant stems. (Data are presented as mean ± SE)

Treatments	Feed intake (g feed/fish)	FCR	PER	PPV (%)	PGR (%/day)
Control (0 stems/m^2)	15.1± 0.29^a	1.39± 0.086^{ab}	2.887± 0.038^{ab}	44.22± 0.589^a	2.393± 0.032^a
25 stems/m^2	14.4± 0.36^a	1.35± 0.0031^a	2.971± 0.068^{ab}	45.407± 1.23^a	2.316± 0.051^a
50 stems/m^2	13.5± 0.41^{ab}	1.32± 0.046^a	3.022± 0.105^a	44.969± 1.568^a	2.235± 0.078^a
75 stems/m^2	12.3± 0.33^{bc}	1.28± 0.075^a	3.122± 0.183^a	47.86± 2.83^a	2.206± 0.129^{ab}
100 stems/m^2	11.7± 0.35^{cd}	1.39± 0.029^{ab}	2.872± 0.057^{ab}	42.13± 0.838^{ab}	2.117± 0.042^{ab}
125 stems/m^2	10.7± 0.29^d	1.57± 0.035^b	2.542± 0.056^b	36.57± 0.778^b	1.908± 0.044^b

Means with the same letter in the same column are not significantly different at P<0.05.

or PGR and vegetation density (r^2 = - 0.9927, - 0.9636 or -0.9823, respectively; Figure 2), while it was positive with FCR (r^2 = 0.9569; Figure 2).

Concerning the chemical proximate analysis of whole fish body, data in Table 3 indicated that the moisture content increased slightly as plant density increased (P>0.05). The maximum moisture content was recorded at the density of 125 stems/m^2 (74.8%; P<0.05), whereas the lowest one was obtained at control (72.4%). The crude protein content was not affected by plant density (56.3% - 58.5%). On the other hand, the lowest value of total lipids was only obtained at plant density of 125 stems/m^2 (25.9%; P<0.05). Contrarily, ash content increased significantly with the increase of plant density in aquarium, and the highest one was obtained at the density of 125 stems/m^2 (15.2%; P<0.05).

Discussion

The lowest fish growth obtained at high plant density agreed to that obtained by Cailteux *et al*.

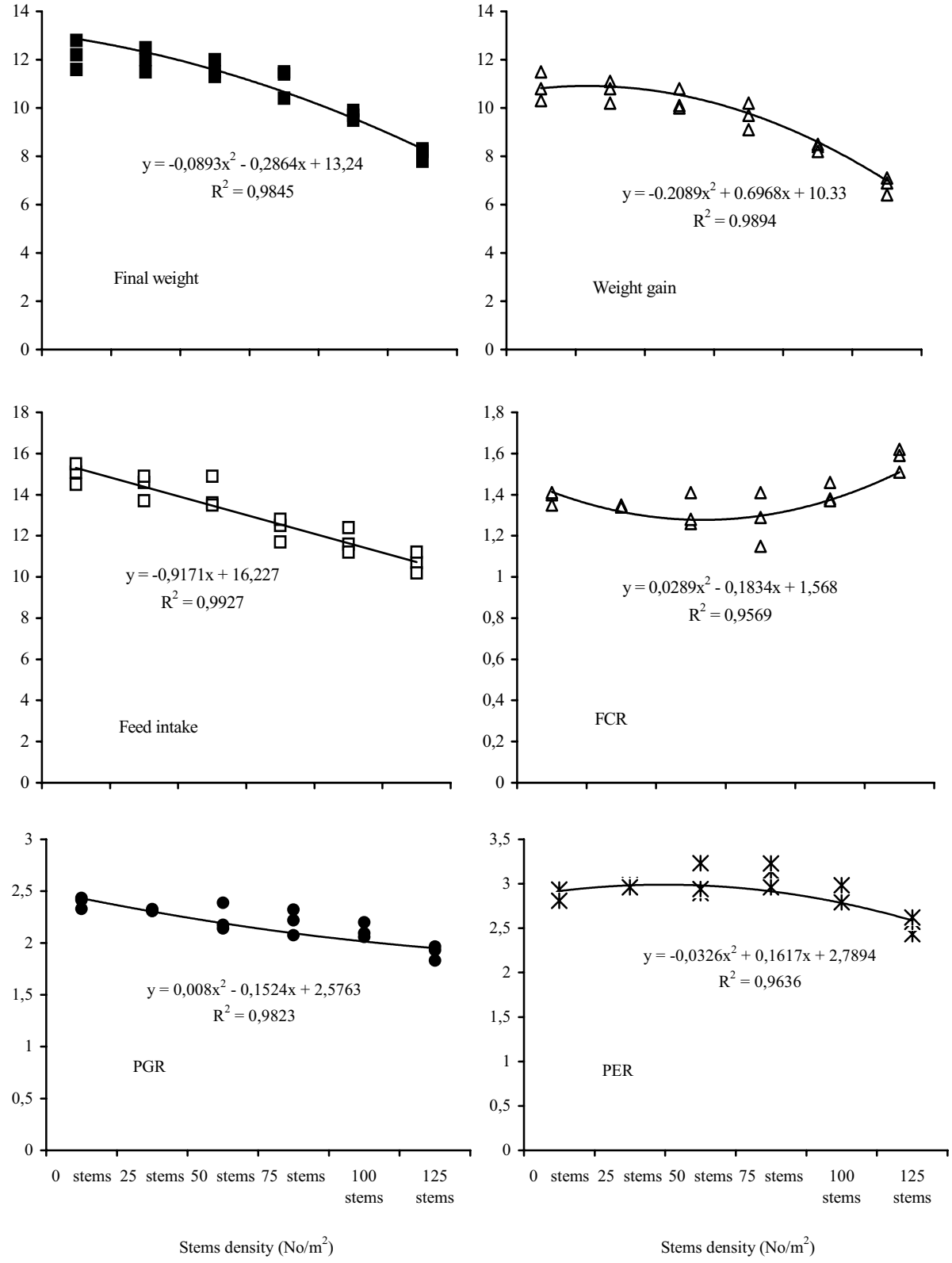

Figure 2. The relationships among stems density in glass aquaria on fish final weight, weight gain, feed intake, FCR, PGR and PER of Nile tilapia.

Table 3. Proximate chemical analyses (%; on dry matter basis) of whole body of Nile tilapia reared in glass aquaria containing different levels of plant stems. (Data are presented as mean ± SE)

Treatments	Moisture	Crude protein	Total Lipids	Ash
Control (0 stems/m^2)	72.4±0.44 [a]	56.3±2.33 [a]	31.3±2.04 [a]	11.7±0.31 [a]
25 stems/m^2	72.6±1.5 [a]	56.6±1.60 [a]	31.3±2.08 [a]	11.5±0.61 [a]
50 stems/m^2	73.2±0.46 [a]	56.5±0.39 [a]	31.2±0.32 [a]	11.8±0.53 [a]
75 stems/m^2	73.1±0.22 [a]	57.8±2.45 [a]	29.7±1.97 [a]	12.2±0.34 [a]
100 stems/m^2	73.7±0.12 [a]	56.9±1.72 [a]	29.3±1.18 [a]	13.5±0.87 [ab]
125 stems/m^2	74.8±0.51 [a]	58.5±1.95 [a]	25.9±1.03 [b]	15.2±0.90 [b]

Means with the same letter in the same column are not significantly different at $P<0.05$.

(1994) who compared the growth of largemouth bass in vegetated versus non-vegetated lakes in central Florida and observed that bass from lakes without aquatic macrophytes grew faster than those in vegetated ones. In addition, Randall *et al*. (1996) found that the high macrophyte density had smaller fish than unvegetated sites. Killigore *et al*. (1989) also reported that fish kept with dense aquatic plants were smaller because their diets were quite similar. Fish moved above or away from plants as they grew larger and changed their feeding preferences. Spitzer *et al*. (2000) found that the growth rate of juvenile pinfish, *Lagodon rhomboides* (Linneaus, 1766) decreased with increasing vegetation density.

Increasing stem density leads to a decrease in light penetration. The low light intensity might be a limiting factor for fish growth because light is an important ecological factor in fish life. The light intensity may directly affect vision of the fish in the water, and indirectly affect the timing of the reproduction and the growth (Lagler *et al*., 1977). Brett (1979) reported that light usually acts as a direct factor stimulating brain-pituitary responses, which radiate through the endocrine and sympathetic systems that induce the production of growth hormone in fish. Moreover, Roesch (1992) found that fish growth and survival were negatively influenced by the low light intensity.

The low feed intake and the subsequent high FCR at high macrophyte densities are probably due to the unsuitable environment for growth. High density of macrophytes may narrow the space that fish can use, which could cause stress on fish that may affect different metabolic pathways. Barton *et al*. (1987) reported that if the duration of stress is extended, the stress response may become maladaptive, and elevated cortisol levels have been reported to be accompanied by reduced growth. The reduced growth may be a result of depressed feeding and/or increased metabolic rate (Morgan and Iwama, 1996). In this regard, Gregory and Wood (1999), and Lyytikainen and Ruohonen (2001) found that the elevation of plasma cortisol has been shown to suppress feed intake. Moreover, the data reported for FCR, PER, PPV and PGR are related to consumption patterns that are affected by restricted feed intake, which essentially was observed as a result of high plant density.

The low fat content in fish body observed at high macrophyte density is related to the difficulty in movement in restricted space where fish may have consumed high energy. In this regard, Crowder and Cooper (1982) postulated that the decline in fish foraging rates with structural complexity is a result of obstruction in fish movements. However, the feeding performance may differ among fish in relation to their maneuverability, a trait which is an asset at high structural densities (Winfield, 1986). In addition, the presence of vegetation in the foraging environment tends to increase fish search time and/or pursuit times (Crowder and Cooper, 1982; Anderson, 1984; Cooks and Streams, 1984; Spitzer *et al*., 2000), which may affect the fat content in the fish body and fish growth.

The natural macrophyte habitat (submerged and emergent) could be more complex than it was simulated herein because I did not use natural plants structure that would be found in a natural pond enclosure. These factors may limit the actual interpretation of the obtained results relative to pond environment. In this concern, Dionne and Folt (1991) showed that plant morphology also affects fish foraging behavior. They found marked variation between the capture rates of pumpkinseed sunfish foraging among leafy stems of *Potamogeton amplifolius* and cylindrical stems of *Scirpus validus*. Also, Savino and Stein (1982) showed that natural vegetation provides more cover than artificial vegetation at similar densities. They predicted that the effect on predator behavior at 250 artificial stem/m^2 (0.4 mm diameter and 0.5 m long) is approximately equal to 130 stems/m^2 of *Potamogeton natans*. In conclusion, fish could use submerged vegetation as a refuge from predators or for periphyton production. So, the vegetation should be at low or moderate density, however, dense vegetation significantly reduces fish growth and feed utilization.

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