Abbassa Int. J. Aqua., V0l.6 No.(1) 2013. *213-228*

EFFECT OF AERATION SYSTEMS AND STOCKING DENSITY ON GROWTH PERFORMANCE, POND YIELD AND ECONOMIC IMPACTS OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*) REARED IN EARTHEN PONDS

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Received 7/4/ 2013 *Accepted 21/5/ 2013*

Abstract

This study was conducted to evaluate the effect of two type of aerator, paddle wheel and toring turbine in ponds with different fish stocking densities (25, 35 and 45 thousand/pond) on growth performace and survival rate and economic impacts.

Nile tilapia fingerlings with average initial body weight of 10.33 ± 0.28 g were allotted randomly into 12 earthen pond (one feddan/each) divided into four treatments. Three stocking densities with two different aeration systems and the control (without aeration) was tested in the present study. The control group without aeration (T_1) was performed in 6 earthen ponds (one feddan area each) and each pond was stocked with 25000 fish. The second treatment (T_2) was performed in two ponds (one feddan area each) and stocked with 25000 fish per pond and ponds were aerated with toring turbine aerators. The third treatment (T_3) included two ponds (one feddan area each) and each pond was stocked with 35000 fish and aerated with paddle wheels. The fourth treatment was performed in two ponds (one feddan each) and stocked with 45000 fish/pond and received aeration through toring turbine aerator. Fish were fed through then experimental period on a diet containing 30.2 % protein at a rate of 3% daily. The study lasted 225 days after start. Results obtained are summarized in the following:

1- Fish of T_2 showed the highest ($P \leq 0.05$) final weight compared to the other treatment groups. The same trend was observed with weight gain and daily gain in weight, while the applied treatments had no significant effects on the specific growth rate.

2- The applied treatments had no significant effects on feed intake per fish, feed conversion ratio or survival rate.

3- The T_4 (45000 fish/pond with toring turine aerator) showed the highest profit index followed in a decreasing order by T_2, T_3 and T_1 respectively.

Based on the obtained results on stocking density of 45000 Nile tilapia per feddan with toring turbine aerator is recommended for pratical aquaculture for higher yield of fish and better profit index.

Key words: Nile tilapia, aeration, stocking density, growth performance

INTRODUCTION

Egypt is the first country for aquaculture production in Africa and the second country for tilapia production in the world after China and the eighth country in the world for aquaculture production (FAO, 2012).

Egypt reported the greatest increase in tilapia production in the last two years, with a reported production of 657086 mt in 2011 (GAFRD, 2012). Other Middle Eastern countries also continue to slowly increase production while also becoming an important global market as guest workers in the region consume considerable amounts of imported tilapia from their home countries. Thus global tilapia production grew to approximately 3.5 million mt in 2011 and should increase to 3.6 million mt in 2012 (Fitzsimmons *et al.*, 2013).

The major production system for Nile tilapia (*Oreochromis niloticus*) is semi-intensive with inorganic or organic fertilizer inputs in earthen ponds with artificial feeds (El-Sayed, 2008).

Dissolved oxygen content of the water of fish ponds is one of the most important parameters of water quality, as the oxygen is a vital condition for all the organisms living in the water and having an aerobic type of respiration (Kepenyes and Váradi, 1984).

Natural aeration of ponds is simulated as a function of the DO saturation in the water and atmosphere, and turbulent mixing at the air/water interface, following Chapra (1997) and Nobre *et al.* (2005).

Artificial aeration means using a mechanical device to bring oxygen levels to the point which ensures the health of the species while maximizing the production goals of the farm. Today’s high intensity farms depend upon accelerated biological activity which tends to outstrip the natural oxygen supply. Artificial aeration then becomes a basic factor in production. Not only does it play a life-saving role in the health of the species, but also a life-saving role in the economics of the farm.

Aeration is important to select an appropriate stocking density level, in order to reach a high enough productivity to produce sufficient revenues to achieve positive profits (El-Sayed, 2006; Forsberg, 1996; Seginer *et al.*, 2008).

There are different types of aerators for different types of ponds. The depth of the pond will usually tell you what type you need. Deeper ponds will normally require a bottom-based diffuser set-up while shallow ponds will typically use a floating aerator. Thorough oxygenation will help break down organic waste more speedily by invigorating beneficial pond bacteria. Aerators can even help with light penetration as surface aerators create such turbulence at the water's surface that sunlight cannot easily penetrate.

Aeration devices such as paddle-wheels, Aire-O2, and more recently, long-armed paddle wheels may be used when culture intensities approach the higher end of semi-intensive systems or in the event of a sudden deterioration of dissolved oxygen levels.

Most owners of large aquaculture farms know the importance of oxygen and employ some artificial means to increase it. Probably the most common type of pond aeration system used by these farmers is some version of the paddle wheel. While any aeration system is better than none, these paddle wheels might not be the best choice for an aquaculture pond. Besides producing large air bubbles that escape the water too quickly, these systems can be relatively high in initial costs and power consumption.

The Toring units are quiet, efficient, and cost effective. Not only is the oxygen transfer efficiency among the highest of all aeration devices, but the capital costs are among the lowest. Because the Toring can be mounted on a floating pontoon, it can be moved from place to place as needed within the pond. The net result is that the Toring will pay for itself in less time that virtually any other aeration system through energy savings, and increased production.

The use of paddle wheels to aerate the water is recommended in order to avoid suboptimal oxygen levels that will aggravate the disease situation.

The aim of this study is evaluate the effect of two type of aerator, paddle wheel and toring turbine and different stocking density on growth performance, survival rate and economic efficiency of earthen ponds.

MATERIALS AND METHODS

This study was conducted at a commercial farm located in Behera Governorate, Egypt where it started at the third week of April 2011 and terminated at the first week of December 2011 (225 days period) to evaluate the effect of two type of aerator, paddle wheel and toring turbine at different fish stocking density on growth performace and survival rate and economic efficiency.

A total number of (360000) mono sex Nile tilapia *(Oreochromis niloticus)* fingerlings of 10.33 ± 0.28 g initial body weight on the average that obtained from nursing pond located at the same farm. The fish were allotted randomly into 12 earthen pond (one feddan/each) divided into four treatments. The control group without aeration (T_1) was performed in 6 earthen ponds (one feddan area each) and each pond was stocked with 25000 fish. The second treatment (T_2) was performed in two ponds (one feddan area each) and stocked with 25000 fish per pond and ponds were aerated with toring turbine aerators. The third treatment (T_3) included two ponds (one feddan area each) and each pond was stocked with 35000 fish and aerated with paddle wheels. The fourth treatment was performed in two ponds (one feddan each) and stocked with 45000 fish/pond and received aeration through toring turbine aerator.

Toring turbine belongs to a class of aeration devices known as self-aspirating aerators. These types of aerators create a subsurface low pressure zone that allows atmospheric pressure to force air through an air tube into the surrounding water, incredible oxygen transfer, 8.5 Kg O_2/Kwh and water flow aproximatly 780 Lit./Sec. the machine used in this study was 2 Hp power.

Paddle wheel consists of a series of paddles which are connected to, and rotate around, a common shaft or axel. As the paddles turn, they cup or scoop air at the surface of the water and force it downward beneath the water level. oxygen transfer is 6.0 Kg O_2/h/paddle and the machine used was of 2 Hp power

Aerator was working daily from sunset and continues throughout the night to after sunrise (approximately 13 h).

Fish were fed on a diets containing (Distillers Dried Grains with Solubles) DDGS and contained 30.2% CP and 3.536 kcal/g ME (Table 1) as reported by Abou Zied and Hassouna (2012). Diets were fed to fish at a rate of 5% of the total body weight at the first month then decreased to 3% until harvesting (225 days duration). Fingerlings were fed 3 times daily at 8 and 11 am and 4 pm 6 days/week. Feed amount was adjusted every 21 days intervals in response to fish weight (fasted 24 h).

Growth and production parameters were initial weight (IW), final weight (FW), average weight gain (AWG), average daily gain (ADG), specific growth rate (SGR), feed conversion ratio (FCR), feed intake(FI), survival rate (SR), net returns and profit index.

Experimental diets were analyzed for their proximate composition in triplicates following the methods described by AOAC (1995). The Metabolizable energy (ME) content of the tested diets were calculated using values of 4.50, 8.15 and 3.49 Kcal for protein, fat and carbohydrate respectively according to Pantha (1982). Water temperature, pH and dissolved oxygen (DO) throughout experimental periods were measured periodically in the morning and at noon by centigrade thermometer, Orion digital pH meter model 201 and oxygen meter, Cole Parmer model 5946 and Hanna instruments ammonia test kit (HI 4829) respectively.

Statistical Analysis:

Data were statistically analyzed using a one- way analysis of variance using SPSS (2010). Mean of treatments were compared by Duncan multiple range test when the differences were significant.

Table (1). Composition and proximate analysis of feed (on as fed basis).

Items	%
Ingredients	
Local fish meal 36 CP%	25.0
Soybean meal 44 CP%	30.0
DDGS 26 CP%	25.0
Wheat bran 12.5 CP%	19.0
Vitamin & minerals	1.0
Total	100
Chemical composition (analyzed)	
DM	89.95
Crude protein, CP	30.16
Ether extract, EE	9.20
Ash	11.13
Crude fiber, CF	6.10
Nitrogen free extract, NFE[1]	32.36
GE, kcal/g[2]	4.150
Metabolizable energy, Kcal/g[3]	3.449

1 ,Calculated by differences
2, Calculated according to NRC (1993).
3, Metabolizable energy (ME):- calculated using values of 4.50, 8.15 and 3.49 K Cal for protein, fat and carbohydrate, respectively according to Pantha (1982).

RESULTS AND DISCUSSION

Water quality:

Water quality parameters measured are shown in Table (2). The values were suitable for the normal growth of tilapia as reported by Tahoun (2007) and Khalfalla *et al.* (2008).

Table (2). Averages water quality parameters throughout the experimental period.

Item	Treatments			
	T_1	**T_2**	**T_3**	**T_4**
Temperature C°	28.0 ± 1.5	28.0 ± 1.5	28.0 ± 1.5	28.0 ± 1.5
Dissolved oxygen	6.1 ± 0.5	7.9 ± 0.6	7.5 ± 0.4	7.5 ± 0.5
pH	7.7 ± 0.3	7.5 ± 0.5	7.8 ± 0.3	7.8 ± 0.4
Ammonia mg/l	0.12	0.12	0.13	0.13

Growth performance

The data presented in Table (3) show that increased final body weight and biomass/pond in aerated pond generally compared with unaerated ponds.

Results of Table (3) reveal that T_2 (toring turbine) had significantly ($P \leq 0.05$) heavier fish final weights compared with T_1 which have the same stocking density of fish but without aeration. On the other hand increasing the stocking density to 35000 fish feddan with paddle wheel or to 45000 fish feddan with toring turbine shown significantly ($P \leq 0.05$) lower final weight compared to T_2, however differences among T_1, T_3 and T_4 in fish final weight were insignificant. The same trend was observed with weight gain and average daily gain where T_2 showed significantly ($P \leq 0.05$) the highest records compared to the other treatment groups. Results of the same table show that average specific growth rate ranged between 1.49 (T_1) to 1.53 (T_2) with insignificant differences among the experimental group.

Table (3). Effect of aeration system and stocking density on growth performance of Nile tilapia at the end of the experimental period.

Parameters	Treatments				SED
	T_1	T_2	T_3	T_4	
Initial mean body weight, g	10.32	10.30	10.25	10.45	0.292
Final mean body weight, g	296.35^{b}	321.76^{a}	301.91^{b}	305.56^{b}	6.179
Weight gain, g (1)	286.04^{b}	311.46^{a}	291.66^{b}	295.11^{b}	6.401
Average daily gain, g (2)	1.27^{b}	1.38^{a}	1.30^{b}	1.31^{b}	0.032
SGR, % /day(3)	1.49	1.53	1.50	1.50	0.055

II. * Average in the same row having different superscripts differ significantly P≤0.05.
* SED is the standard error of difference
Experimental period = 255 days
(1) = Final weight - Initial weight
(2) = Weight gain, g /period in days.
(3) = 100 (ln Final weight-ln Initial weight)/period in days, where ln is the natural log.

These results agreed with that obtained by Teichert-Coddington and Green (1993) who reported that tilapia yield and individual final size were significantly greater in aerated ponds than in unaerated ponds, they added that aeration could enhance yields, but had little effect on water quality other than increasing turbidity. In aerated ponds (T_3 and T_4) the results cleared that differences in growth parameters were insignificant due to increased stocking density above the aeration facilities. These results are agreement with that obtained by Hargreaves *et al.* (1991), who demonestrated that using aeration at high stocking density improved growth without problems. Ruiz-Velazco *et al.* (2010) showed that shrimp production could be increased at harvesting by raising aeration horsepower and increasing the shrimp biomass. On the other hand, starting aeration at the beginning of the culture cycle resulted in increased yield while starting after 5 weeks decreased the yield.

Feed utilization:

Results of Table (4) illustrate that stocking density and aeration released insignificant effects on feed utilization parameters. Results cleared also that insignificant differences were recorded among all treatments except feed intake which increased significantly in T_2 than T_1 (same density and unaerated) but T_3 and T_4 were similar. These results may be due to increased oxygen concentration which improved appetite of fish to consume more feed. The best insignificant record FCR was found in T_2 with low socking density and aerated by Toring turbine than other treatment. But the worst (highest) FCR were found in T_3 which used paddle wheel and stocking density 35000 fish/pond.

Table (4). Effect of aeration system and stocking density on feed utilization of Nile tilapia through the experimental period.

Parameters	Treatments				SED
	T_1	T_2	T_3	T_4	
Feed intake, g/fish	589.34^{b}	625.98^{a}	607.73^{ab}	604.94^{ab}	13.159
FCR	2.06	2.01	2.08	2.05	0.071
Survival rate%	91.97	95.85	90.50	90.00	0.857
Feed intake, kg/pond	13550	15000	19250	24500	422.5

* Average in the same row having different superscripts differ significantly $P \leq 0.05$.
* SED is the standard error of difference

Survival rate was the best (highest) in T_2 than other treatments which were almost similar. All these results are agreement with these obtained by Hollerman and Boyd (1980), Sanares *et al.* (1986), Lai-Fa and Boyd (1988), Boyd, (1990), Hargreaves *et al.* (1991) and Teichert-Coddington and Green, (1993) and survival as reported by Jena *et al.* (2007 and 2008) in fingerlings rearing and grow-out system under polyculture. Lefevre *et al.* (2011) reported that aeration should decrease the amounts of toxic compounds present in the deeper water in the ponds (ammonia, nitrite, and possibly hydrogen sulfide) and thus make a greater proportion of pond volume available for the fish, allowing for higher stocking densities.

Economic Efficiency:

Results of table (5) include the costs and returns of one feddan as affected with stocking density and aeration method. Results revealed that the total costs in LE per feddan were 45375; 51000; 64125 and 78750 LE for treatments T_1; T_2; T_3 and T_4 respectively. The higher total costs reported for T_3 and T_4 had due to the higher inputs for fish fry and feed required throughout the experimental period for with groups. The higher total costs of T_2 compared to T_1 had due to the higher costs of feed and electrical power thus the stocking density of fish was the same. As presented in the same table the net return for T_1; T_2; T_3 and T_4 were 7515; 11150; 11875 and 19150 LE, respectively indicating that increasing density of tilapia to 45000 fish/feddan increased the net returns when toring turbine aeration was applied. Furthermore the profit index was 1.17; 1.22; 1.19 and 1.24 for T_1; T_2; T_3 and T_4 respectively indication that applying aeration with toring turbine increased the profit index using higher stocking density.

Table (5). Effect of aeration system and stocking density on economic efficiency of Nile tilapia through the experimental period.

Parameters	**Treatment**			
	T_1	**T_2**	**T_3**	**T_4**
Costs, L.E/pond (one feddan)				
Feed	33875	37500	48125	61250
Fish	5000	5000	7000	9000
Other costs (labor, power, …)	6500	8500	9000	8500
Total costs, L.E.	45375	51000	64125	78750
Pond biomass, kg	6815	7710	9560	12375
Selling price, L.E/ pond	52890	62150	76000	97900
Net returns/pond	7515	11150	11875	19150
Profit index	1.17	1.22	1.19	1.24

Price of one kg selling fish = 8.5, 6.0 and 4 L.E for super, first and second grade respectively.
Price of kg feed = 2.50,

CONCLUSION

Aerator machine caused improved growth performance and feed utilization and economic efficiency for fish ponds and increased density without problems in oxygen than unaerated ponds but aerated machine different in optimum stocking density. Toring turbine showed the best aerator than paddle wheel.

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تأثير أنظمة التهوية وكثافة التخزين على مظاهر النمو وإنتاج الحوض والتأثير الاقتصادى للبلطى النيلى المربى فى الأحواض الأرضية

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أجريت هذه الدراسة لتقييم تأثر نوعين من وسائل التهوية، البدالات الهوائية والتربينات فى الاحواض، باستخدام كثافات مختلفة من اسماك البلطي ٤٥،٣٥،٢٥ ألف/ حوض على مقاييس النمو والإعاشة والناتج الاقتصادي .

وزعت اصبعيات البلطي النيل بمتوسط وزن ١٠.٣٣± ٠.٢٨ جم عشوائيا على ١٢ حوض ترابى (فدان/حوض) وقسمت إلى ٤ معاملات. ثلاثة كثافات مع التهوية والكنترول بدون تهويه والتى اختبرت فى هذه التجربة.

مجموعة المقارنة بدون تهوية (المعاملة الأولى) مثلث في ٦ أحواض (مساحة الحوض فدان) وخزن بكل حوض ٢٥٠٠٠ سمكة. العاملة الثانية مثلث في حوضين بكثافة ٢٥٠٠٠/حوض مع التهوية بالتربينات. المعاملة الثالثة مثلت فى حوضين بكثافة ٣٥٠٠٠سمكة/حوض مع التهوية بالبدالات الهوائية والمعاملة الرابعة مثلت فى حوضين بكثافة ٤٥٠٠٠سمكة/حوض مع التهوية بالتربينات. غذيت الاسماك خلال فترة التجربة بعليقة تحتوى ٣٠.٢% بروتين بمعدل ٣% يوميا واستمرت التجربة ٢٢٥ يوما وكانت النتائج المتحصل عليها كالتالى:

١- اسماك المعاملة الثانية تفوقت معنويا فى الوزن النهائى مقارنة بباقى المعاملات. ولوحظ نفس الاتجاه مع الوزن المكتسب والزيادة اليومية بينما لم يكن هناك تأثير معنوى على معدل النمو النوعى.

٢- لم يكن هناك تأثير معنوى للمعاملات على الغذاء المأكول للسمكة ومعدل التحويل الغذائى والاعاشة.

٣- المعاملة الرابعة (٤٥ الف سمكة/حوض مع التهوية بالتربينات) اظهرت اعلى دليل للربحية تبعها تنازليا المعاملة الثانية والثالثة والاولى على الترتيب.

استنادا على النتائج المتحصل عليها مع الكثافة التخزينية ٤٥ الف بلطى نيلى /فدان مع التهوية بالتربينات يوصى بها فى الاستزراع السمكى وذلك للانتاج العالى من الاسماك مع تحسن مؤشرات الربحية.