Impact of mono or polyculture systems on water quality, growth performance and economic efficiency of *Oreochromis niloticus* (Linnaeus, 1758) and *Hypophthalmichthys molitrix* (Valenciennes, 1844)

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**ABSTRACT**

The aim of this study was to investigate the effect of the graded replacement of stocking density rate (0, 4, 8 and 12%) of the monosex *Oreochromis niloticus* by the silver carp, *Hypophthalmichthys molitrix* as a mono (T₁) or poly-culture systems (T₂, T₃, and T₄, respectively) for 124 days (4 months) on water quality parameters, growth performance and feed efficiency parameters, condition factor, fish organs indices, fish body composition. The total production of *O. niloticus* and economic efficiency parameters were evaluated in each treatment. An experimental field study was conducted in covered floating net cages in the Lake Manzala. The obtained results revealed the positive effects of rearing *O. niloticus* in poly-culture systems with *H. molitrix* compared to mono-culture system of *O. niloticus* (T₁). *O. niloticus* reared in poly-culture system at stocking rate 4% (T₂) or 8% (T₃) with *H. molitrix* significantly (*P* ≤ 0.05) improved the growth rate, feed efficiency (feed intake, feed conversion ratio, protein and energy utilization), and chemical composition of the fish body (crude protein, ether extract, energy content) parameters of both fish species. While, *O. niloticus* reared in poly-culture system with 12% silver carp (T₄) gave the highest total output, total profit, and economic efficiency (%) among all the experimental mono (T₁) or poly-culture systems with silver carp (T₂ and T₃). Thus, it could be concluded that monosex *O. niloticus* reared with *H. molitrix* at 4% (T₂), and 8% (T₃) in poly-culture systems are the best aquaculture systems among the experimental mono (T₁) or other poly-culture system with 12% *H. molitrix* (T₄). But economically, *O. niloticus* reared in poly-culture system with 12% silver carp (T₄) is the best aquaculture system among all the experimental systems.

**Keywords:** Nile tilapia, Silver carp, Aquaculture, Growth performance, Lake Manzala

**INTRODUCTION**

Aquaculture is currently the largest single source of fish supply in Egypt accounting for almost 77% (1.1 million ton) of the total fish production of the country with over 99% produced from privately owned farms (GAFRD, 2014). This sector is exhibiting the strongest growth of any fisheries related activity in the country and as a result aquaculture is considered as the only viable option for reducing the gap between production and consumption of fish in Egypt. Partially, fish cage culture system also widely used especially in the Nile Delta region where semi-intensive and intensive farming is practiced with a total production in 2014 reaching to 176266 tonnes (as 11.89% of the total fish production, GAFRD, 2014). Intensive fish cage culture is rapidly developing and now contributes to around 10% of total aquaculture production in Egypt. Nile tilapia, *Oreochromis niloticus* is the principal cage culture species. The sizes of the cages vary from small cages of around 32 m³ to larger cages of around...
600 m$^3$. Smaller cages (2-4 m$^3$) suspended in drainage canals are also used in rural areas. The yield varies between 5 to 35 kg/m$^3$ (El-Sayed, 2007).

Lake Manzala has gradually transformed, with time, from a brackish environment (Bishai and Yossef, 1977) to eutrophic fresh water in response to increased drainage water inputs, nutrient loading associated with agricultural land reclamation processes and due to the urban waste disposal. Polyculture of species combinations with compatible feeding habits can help in maximizing primary productivity and reducing nutrient discharges. It may be possible in suitable situations to use minimum water exchange systems successfully (Avnilmech, 1998) in intensive fish farming. Nile tilapia and silver carp are cultured and stocked in commercial ponds and known to be effective in managing nuisance phytoplankton blooms in both eutrophic lakes (Starling, 1993; Fukushima et al., 1999) and aquaculture ponds (Brune et al., 2001; Mueller, 2001). Both species are reported to selectively filter water based on particle size. Hence, the present study was designed as an attempt to improve monosex Nile tilapia, *O. niloticus* production in Lake Manzala, through the graded replacement of stocking density rate (0, 4, 8 and 12%) of *O. niloticus* by silver carp, *Hypophthalmichthys molitrix* as a mono (*T_1*) or poly-culture systems (*T_2*, *T_3*, and *T_4*, respectively) in floating net cages for 124 days (4 months). The impacts of these aquaculture systems were studied on water quality parameters, growth and feed efficiency parameters, condition factor, fish organs indices, fish body composition. The total production of *O. niloticus* through the graded of their body size, as well as the total production, total output, and the economic efficiency parameters of each treatment were evaluated.

**MATERIALS AND METHODS**

**Experimental management:**

The present study was carried in a private fish cages farm in Lake Manzala, (Raswah Lisa Al-Gamaliah), Dakahlia Governorate, Egypt. Mono-sex Nile tilapia, *O. niloticus*, (Linnaeus, 1758) with an average initial body weight (19.30 ± 3.81 g) and / or silver carp, *H. molitrix* (Valenciennes, 1844) with an average initial body weight (73.67 ± 10.11 g) were used in this experiment. *O. niloticus* fingerlings were purchased from El-Manzala hatchery, Integrated Fish Farm at El-Manzala (General Authority for Fish Resources Development-Ministry of Agriculture), Dakahlia Governorate, Egypt. While, silver carp were purchased from a private Fish Farm of Yousef Asal, Raswah, Lisa Al-Gamaliah, Dakahlia Governorate, Egypt.

The experimental fish were adapted for two weeks in floating covered net-cages and fed on the basal diet during this adaptation period. Fish randomly distributed into four floating covered net-cages (10 m length × 10 m Width × 2 m depth), as four experimental groups as shown in Table 1 and Figure 1.

<table>
<thead>
<tr>
<th>Treatment (cage)</th>
<th>No. of Nile tilapia</th>
<th>No. of Silver carp</th>
<th>Total biomass of cage (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st (Nile tilapia mono aquaculture system)</td>
<td>6000</td>
<td>------</td>
<td>115.50</td>
</tr>
<tr>
<td>2nd (Nile tilapia and 4% silver carp in poly-culture system)</td>
<td>5760</td>
<td>240</td>
<td>129.00</td>
</tr>
<tr>
<td>3rd (Nile tilapia and 8% silver carp in poly-culture system)</td>
<td>5520</td>
<td>480</td>
<td>142.00</td>
</tr>
<tr>
<td>4th (Nile tilapia and 12% silver carp in poly-culture system)</td>
<td>5280</td>
<td>720</td>
<td>155.50</td>
</tr>
</tbody>
</table>
Impact of mono or polyculture systems on water quality *O. niloticus* and *H. molitrix*

All fish groups were fed on the same artificial pelleted diet (about 25% crude protein), which purchased from AboAbbas Animal Feed Factory, the industrial zone El-Asafra, Al-Matariah, Dakahlia Governorate, Egypt. The ingredients of the artificial diet and its chemical composition are illustrated in Table 2. The artificial diet was offered manually to the fish in all treatment twice daily at 9.00 a.m. and 15.00 p.m. The feeding rate was 4% for the three months of the experiment and decreased to 3% of body weight mass till the end of the experiment. The feed quantity was adjusted biweekly on the basis of the actual changes on biomass of the fish in each cage.

Table 2: Formulation and chemical analysis (% on dry matter basis) of the experimental diet

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Gram per kg diet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moroccan fish meal (65% CP)</td>
<td>60.00</td>
</tr>
<tr>
<td>Corn gluten (60% CP)</td>
<td>40.00</td>
</tr>
<tr>
<td>Soybean meal (48% CP)</td>
<td>250.00</td>
</tr>
<tr>
<td>Wheat bran (14% CP)</td>
<td>200.00</td>
</tr>
<tr>
<td>Rice bran (14% CP)</td>
<td>250.00</td>
</tr>
<tr>
<td>Yellow corn (9% CP)</td>
<td>180.00</td>
</tr>
<tr>
<td>Salts</td>
<td>20.00</td>
</tr>
<tr>
<td>Total</td>
<td>1000.0</td>
</tr>
</tbody>
</table>

Nutrient composition

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry matter (DM%)</td>
<td>90.50</td>
</tr>
<tr>
<td>Crude protein (CP %)</td>
<td>24.05</td>
</tr>
<tr>
<td>Ether extract (EE %)</td>
<td>5.55</td>
</tr>
<tr>
<td>Crude fiber (%)</td>
<td>7.55</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>8.75</td>
</tr>
<tr>
<td>Nitrogen free extract (%)</td>
<td>54.10</td>
</tr>
<tr>
<td>Total carbohydrates (%)</td>
<td>61.65</td>
</tr>
<tr>
<td>Gross energy (GE)¹ (Kcal / 1000 g DM)</td>
<td>441.41</td>
</tr>
<tr>
<td>Protein / energy (P/E)² ratio (mg CP / Kcal GE)</td>
<td>54.48</td>
</tr>
</tbody>
</table>

¹GE (Kcal / 100 g DM) = CP × 5.64 + EE × 9.44 + Total carbohydrates × 4.11 calculated according to (Macdonald et al., 1973).

²P/E ratio (mg protein / Kcal GE) = (CP × 1000) / GE.

Criteria measured:

Some of water quality parameters were measured in all experimental cages as following; water temperature, dissolved oxygen (DO), ammonia and pH values at the start and weekly in all the experimental period. Whereas, water temperature in degree centigrade was recorded using a thermometer and DO concentration was determined...
using the Winkler method (APHA, 1971). Ammonia and pH values of water was measured by direct Nesslerization methods using a CHEMETS® test kits (CHEMETRICS, INC, USA) according to APHA (1992).

Body weight of monosex *O. niloticus* in each cage were measured biweekly, while the body weight of *H. molitrix* were measured at the start and the end of the experiment to limited feed quantity and to calculate the growth performance and feed utilization according to Halver and Hardy (2002). Also, at the start and the end of the experiment, all fish species (*O. niloticus* and *H. molitrix*) were sampled from each cage and kept frozen (−20°C) until the chemical analysis was done. The chemical analysis of the experimental diet and the whole fish body was carried out according to AOAC (2004).

At the end of the experiment, ten *O. niloticus* were randomly taken from each treatment and anaesthetized then individually weighed and their total length was measured to calculated the condition factor (Kf) according to the following equation; 

\[ K_f = \frac{\text{fish weight (g) \times 100}}{\text{total length}^3 \text{ (cm)}} \] (Lagler, 1956). Also, at the end of the study the same ten fish used for determination Kf-values were anaesthetized by pure clove oil. Then fish were individually weighed, sacrificed, and the internal organs livers, spleen, and intestine were individually removed and weighed also to calculate the organs indices according to the following equations; hepato-somatic index (HSI) = (liver weight/ fish weight) × 100 (Jangaard *et al.*, 1967), spleen-somatic index (SSI) = (spleen weight / fish weight) × 100, and intestine-somatic index (ISI) = (intestine weight / fish weight) × 100 (Tseng and Chan, 1982).

At the end of the experiment, total production of all fish species (kg) and total output (LE) parameters were calculated according to the total weight gain costs (as output) and food consumption costs (as input) regardless to any other costs. While, the graded of *O. niloticus* according their body size in each cage was done, where the fish size was consider as; size 1: 300 – 500g, size 2: 200 – 250g, size 3: 100 – 150g, and size 4: 50 - 100g.

**Statistical analysis:**

The obtained data was subjected to one-way analysis of variance (ANOVA) using professional statistical analysis system (SAS, 2006) software version 9.1.3. All ratios and percentages were arcsine-transformed prior to statistical analyses. Mean of each treatment were statistically compared for the significance \((P \leq 0.05)\) using Duncan's multiple range test (Duncan, 1955), evaluated by the following model:

\[ Y_{ij} = \mu + T_i + e_{ij} \]

Where:

- \(Y_{ij}\) = the data of growth performance, feed efficiency, Kf and organs indices, and fish body composition parameters; \(\mu\) = the overall means; \(T_i\) = the fixed effect of treatments; \(e_{ij}\) = is the random error.

While, all data of the water quality parameters in different treatments and in different times were statistically analyzed using SAS (2006), with factorial design (4×4) and evaluated using the following model:

\[ Y_{ijk} = \mu + L_i + P_j + LP_{ij} + e_{ijk} \]

Where:

- \(Y_{ijk}\) = the data of water quality parameters; \(\mu\) = the overall means; \(L_i\) = the fixed effect of the different treatments (four treatments); \(P_j\) = the fixed effect of different times (Four months); \(LP_{ij}\) = the interaction effect between the effect of treatments (four treatments) and / or different times (Four months) on water quality parameters; \(e_{ijk}\) = is the random error.
RESULTS AND DISCUSSION

Water quality parameters:

No significant ($P \geq 0.05$) effects of mono or polyculture systems (treatments, Table 3) or the interaction between mono or poly-culture systems and different experimental times were found on all water quality parameters. In the 3rd period (September - October), water pH-value, and water temperature have significantly ($P \leq 0.05$) increased, while water-NH$_3$, and dissolved oxygen (DO) were significantly ($P \leq 0.05$) decreased comparing to other experimental periods. Although, these significant differences of water quality parameters were within the suitable range for fish culture (Abdelhamid, 2011), except water DO. Where, DO seriously decreased in all cages and in all experimental period, especially in summer. Additionally, the discharge of agricultural, domestic and industrial wastes with high biological oxygen demand, nutrient, heavy metals, and pesticides have led to a deterioration in water quality and eutrophicated conditions in large areas of Lake Manzala (Ayache et al., 2009). Moreover, cages sites that are strongly stratified for much of the year, and/or where algal blooms carry risks of periodically poor oxygen condition, should be avoided if possible. Marine sites which have good bottom currents and which disperse sedimenting wastes are desirable. Warm-water fish survive at DO levels as low as 1 mg / L, but their growth is slowed down by prolonged exposure, whereas the desirable range of DO is above 5 mg / L.

<table>
<thead>
<tr>
<th>Treatment (cage)</th>
<th>pH (±0.13)</th>
<th>NH$_3$ (mg / L)</th>
<th>DO (mg / L)</th>
<th>Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.25 ± 0.13</td>
<td>0.0016 ± 0.00</td>
<td>2.40 ± 0.16</td>
<td>26.60 ± 0.81</td>
</tr>
<tr>
<td>2</td>
<td>7.25 ± 0.13</td>
<td>0.0016 ± 0.00</td>
<td>2.66 ± 0.20</td>
<td>26.60 ± 0.81</td>
</tr>
<tr>
<td>3</td>
<td>7.25 ± 0.13</td>
<td>0.0017 ± 0.00</td>
<td>2.30 ± 0.17</td>
<td>26.60 ± 0.81</td>
</tr>
<tr>
<td>4</td>
<td>7.25 ± 0.13</td>
<td>0.0013 ± 0.00</td>
<td>2.66 ± 0.18</td>
<td>26.60 ± 0.81</td>
</tr>
<tr>
<td>P-value</td>
<td>1.00</td>
<td>0.1999</td>
<td>0.2350</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Mean in the same column having different small letters are significantly different ($P \leq 0.05$). DO: Dissolved oxygen

Fish growth performance:

All growth performance parameters of *O. niloticus* reared in poly-culture systems ($T_2$, $T_3$ and $T_4$) were significantly ($P \leq 0.05$) increased comparing to the *O. niloticus* reared in mono-culture system ($T_1$), where the highest growth performance parameters were recorded in $T_2$ compared to other groups (Table 4). Regarding the growth performance of *H. molitrix* reared in poly-culture systems, the same treatment $T_2$ (4% *H. molitrix*) had a significant ($P \leq 0.05$) increased of all growth performance parameters of *H. molitrix* among other poly-culture systems 8% ($T_3$) and 12% ($T_4$) of *H. molitrix*, respectively (Table 4).

Growth is an important component of the ecology of fishes (Wootton, 1992). In the present study, the growth performance of *O. niloticus* or *H. molitrix* has been
improved \((P \leq 0.05)\) in poly-culture systems than mono-culture system. As the current findings also, Sweilum (1995) found that the body length and weight of Nile tilapia and silver carp slightly increased by decreasing the stocking density rate. In addition, Sweilum (2001) obtained better growth rate and production for \(O. \text{ niloticus}\) in poly-culture combination \((Sarotherodon \text{ galilaeus} \text{ and Clarias gariepinus})\) than in duo-culture and mono-culture systems. On other hand, Sweilum (1998 a) reported that growth and production of \(O. \text{ niloticus}\) are related to stocking density, since they increase at low density. Also, El-Saidy and Gaber (2002) confirmed the same conclusion for \(O. \text{ niloticus}\), which were significantly \((P \leq 0.01)\) the best growth performance at the lower stocking density; while, total production and net production exhibited significantly the opposite trend. In this respect, Hassan \(et \ al\). (2006) noticed that increasing the stocking density significantly decreased body weight and length of tilapia aurea. Inversely, Abdelhamid (2011) recommended that the best treatment is the monoculture of all males monosex \(O. \text{ niloticus}\) reared in net cages followed by that of poly-culture for their superiority in growth and feed efficiency parameters.

Due to their rapid growth rate and worldwide popularity, silver carp is not considered threatened. They are often sold for human consumption and are also used for cleaning waters of algael blooms (Smith, 1989). In general, silver carp can adapt to many different environments and can grow very quickly, as well as silver carp gained 2.7 g / day when fed on a large diet. Similarly with the obtained results herein, Bakeer \(et \ al\). (2003) revealed that silver carp cultured in cages gave pronounced \((P \leq 0.05)\) increases in body weights at lower stocking density. In addition, Sweilum (1998 b) noticed that the silver carp was the best species in tilapia rearing ponds, where weight gain of \(O. \text{ niloticus}\) reached its maximum value.

<table>
<thead>
<tr>
<th>Treatment (cage)</th>
<th>Final weight (g)</th>
<th>Average weight gain (g)</th>
<th>ADG (g/fish/day)</th>
<th>RGR (g)</th>
<th>SGR (%/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>O. niloticus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>84.13(\pm) 1.20</td>
<td>64.83(\pm) 1.20</td>
<td>0.52(\pm) 0.01</td>
<td>335.90(\pm) 6.19</td>
<td>1.18(\pm) 0.01</td>
</tr>
<tr>
<td>2</td>
<td>100.58(\pm) 0.59</td>
<td>81.28(\pm) 0.58</td>
<td>0.65(\pm) 0.00</td>
<td>421.10(\pm) 2.97</td>
<td>1.33(\pm) 0.00</td>
</tr>
<tr>
<td>3</td>
<td>96.67(\pm) 1.84</td>
<td>77.36(\pm) 1.83</td>
<td>0.62(\pm) 0.01</td>
<td>400.80(\pm) 9.49</td>
<td>1.29(\pm) 0.02</td>
</tr>
<tr>
<td>4</td>
<td>97.46(\pm) 0.98</td>
<td>78.16(\pm) 0.98</td>
<td>0.63(\pm) 0.01</td>
<td>405.00(\pm) 5.07</td>
<td>1.31(\pm) 0.01</td>
</tr>
<tr>
<td>P-value</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
<tr>
<td>H. molitrix</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>227.50(\pm) 2.65</td>
<td>153.80(\pm) 2.65</td>
<td>1.24(\pm) 0.02</td>
<td>208.80(\pm) 3.59</td>
<td>0.90(\pm) 0.01</td>
</tr>
<tr>
<td>3</td>
<td>219.20(\pm) 5.27</td>
<td>145.50(\pm) 5.27</td>
<td>1.17(\pm) 0.04</td>
<td>197.60(\pm) 7.16</td>
<td>0.87(\pm) 0.02</td>
</tr>
<tr>
<td>4</td>
<td>179.50(\pm) 1.02</td>
<td>105.80(\pm) 1.02</td>
<td>0.85(\pm) 0.01</td>
<td>143.70(\pm) 1.39</td>
<td>0.71(\pm) 0.00</td>
</tr>
<tr>
<td>P-value</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Mean in the same column having different small letters are significantly different \((P \leq 0.05)\). ADG: average daily gain, RGR: relative growth rate, and SGR = specific growth rate

Chemical composition of fish body:

Results in Table 5 revealed that \(O. \text{ niloticus}\) reared in poly-culture system with 8% silver carp (T3) had a significant \((P \leq 0.05)\) highest DM content among the experimental fish reared under mono (T1) or poly-culture systems (T2, and T4). Also, fish in T2 group (4% poly-culture system by silver carp) gave the highest \((P \leq 0.05)\) EE and EC among all fish groups. However, \(O. \text{ niloticus}\) reared in mono-culture
system (T1) had highest \((P \leq 0.05)\) CP and ash contents compared to fish reared under the poly-culture systems (T2, T3, and T4). Also, data in Table 5 illustrated the body composition of *H. molitrix* reared under poly-culture systems (T2, T3, and T4). *H. molitrix* reared under 8% poly-culture system (T3) had significant \((P \leq 0.05)\) highest DM and ash contents among fish reared under other poly-culture systems (T2, and T4). While, fish reared in 4% poly-culture system (T2) gave highest \((P \leq 0.05)\) CP and EC compared to fish reared in other poly-culture systems (T3, and T4). No significant \((P \geq 0.05)\) effects on EE content of fish reared in all poly-culture systems.

The obtained results regarding the body composition of the experimental fish (*O. niloticus* or *H. molitrix*) revealed that the poly-culture systems of fish at 8% (T3) followed by 4% (T2) significantly improved the body composition of fish compared to mono-culture system (T1) or the poly-culture system (12%, T4). These results were confirmed by the markedly significant effects of these poly-culture systems (T2 and T3) on all growth performance parameters of *O. niloticus* or *H. molitrix* (Table 4) among all groups. *O. niloticus* have the ability to filter-feed on phytoplankton (Turker et al., 2003a,b), and concomitantly produce a second crop of marketable animal in poly-culture systems (Dos Santos and Valentí, 2002). In this respect, tilapias are considered filter feeders because they can efficiently harvest plankton from the water. They can digest more efficiently the plant protein (Popma and Masser, 1999). Under the poly-culture system of Nile tilapia and silver carp, Soltan (1998) had the same results for Nile tilapia and the opposite results were obtained with silver carp stocked with Nile tilapia in the same pond. Also, the current findings agree with those obtained by Shaker and Mahmoud (2007) in case of silver carp reared in cages in River Nile.

### Table 5: Effect of the experimental mono or poly-culture systems in cages on body chemical composition parameters (% on dry matter basis) of *Oreochromis niloticus* and *Hypophthalmichthys molitrix*

<table>
<thead>
<tr>
<th>Treatment (cage)</th>
<th>DM (%)</th>
<th>CP (%)</th>
<th>EE (%)</th>
<th>Ash (%)</th>
<th>EC (kcal / 100 g)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>O. niloticus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At the start:</td>
<td>20.86</td>
<td>59.47</td>
<td>13.61</td>
<td>26.92</td>
<td>463.88</td>
</tr>
<tr>
<td>At the end:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>22.72±0.17</td>
<td>58.19±0.40</td>
<td>21.54±0.14</td>
<td>20.26±0.53</td>
<td>531.6±3.51</td>
</tr>
<tr>
<td>2</td>
<td>22.27±0.63</td>
<td>55.64±0.08</td>
<td>28.55±0.28</td>
<td>15.80±0.36</td>
<td>583.4±3.07</td>
</tr>
<tr>
<td>3</td>
<td>24.30±0.28</td>
<td>57.04±0.32</td>
<td>26.19±0.13</td>
<td>16.76±0.29</td>
<td>569.0±1.65</td>
</tr>
<tr>
<td>4</td>
<td>22.74±0.39</td>
<td>55.50±0.32</td>
<td>27.49±0.18</td>
<td>17.00±0.16</td>
<td>572.6±0.50</td>
</tr>
<tr>
<td><strong>H. molitrix</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>At the start:</td>
<td>19.49</td>
<td>68.20</td>
<td>9.75</td>
<td>22.05</td>
<td>476.68</td>
</tr>
<tr>
<td>At the end:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>16.09±0.14</td>
<td>70.33±0.23</td>
<td>7.73±0.07</td>
<td>21.94±0.22</td>
<td>469.60±1.27</td>
</tr>
<tr>
<td>2</td>
<td>17.23±0.53</td>
<td>67.31±0.32</td>
<td>7.40±0.26</td>
<td>25.28±0.20</td>
<td>449.50±1.55</td>
</tr>
<tr>
<td>3</td>
<td>15.64±0.22</td>
<td>68.47±0.53</td>
<td>7.45±0.35</td>
<td>24.08±0.22</td>
<td>456.50±1.01</td>
</tr>
<tr>
<td><strong>P-value</strong></td>
<td>0.033</td>
<td>0.0008</td>
<td>0.0001</td>
<td>0.0001</td>
<td></td>
</tr>
</tbody>
</table>

Mean in the same column having different small letters are significantly different \((P \leq 0.05)\). DM: Dry matter, CP: Crude protein, EE: Ether extract, and EC: Energy content.

### Condition factor (Kf) and internal organs indices:

Condition factor (Kf) and organs indices, now usual practice in fisheries biology, and have also been used to evaluate the fitness of fish populations (Bolger and Connolly, 1989). In the present study, no significant \((P \geq 0.05)\) effects were
detected on K_f or the organs indices (HSI%, SSI%, and ISI%) parameters of O. niloticus reared in mono or poly-culture systems (Table 6). Additionally, knowledge of some quantitative characteristics in fishes is an important tool for the study of biological fundamentals such as viscerosomatic and hepatosomatic indices, because measurement and analysis of these indices are very important in assessing food value (Ighwela et al., 2014), and fish health (Sadekarpawar and Parikh, 2013). Although, the poly-culture systems significantly improved of all growth performance parameters (Table 4) of O. niloticus, but no significant (P ≥ 0.05) effects were detected on K_f or the organs indices of O. niloticus reared in the poly-culture systems. The rate of growth of fish is highly variable because it is greatly dependent on a variety of interacting environmental factors such as water temperature, levels of DO and ammonia, salinity, and photoperiod (Brogowski et al., 2005). Generally, the growth-dependent variations of trace element levels are known to be influenced by various factors such as metabolic rate, and growth dilution of the elements (Langston and Spence, 1995).

Length-weight relationship is widely used procedure to assess the growth performances of fish (Morato et al., 2001). According to Mendes et al. (2004), length-weight relationship is one of the most commonly used analyses of fisheries data. Along with length-weight relationship, studies on K_f provide a robust indication of fish health. As in the present findings herein, when K_f was greater than 1, it can be concluded that fish reared in cages were in good condition and healthy (Gupta et al., 2012). It also means that the growth of tilapia in cages was good as K_f has been used as an index for growth studies (Fagade, 1979).

Table 6: Effect of the experimental mono or poly-culture systems in cages on condition factor (K_f) and different organs indices parameters of Oreochromis niloticus

<table>
<thead>
<tr>
<th>Treatment (cage)</th>
<th>K_f (%)</th>
<th>HSI (%)</th>
<th>SSI (%)</th>
<th>ISI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.69 ± 0.08</td>
<td>2.49 ± 0.24</td>
<td>0.33 ± 0.10</td>
<td>5.44 ± 0.71</td>
</tr>
<tr>
<td>2</td>
<td>1.72 ± 0.02</td>
<td>1.82 ± 0.40</td>
<td>0.25 ± 0.07</td>
<td>4.41 ± 0.23</td>
</tr>
<tr>
<td>3</td>
<td>1.79 ± 0.05</td>
<td>2.91 ± 0.02</td>
<td>0.34 ± 0.12</td>
<td>5.79 ± 1.39</td>
</tr>
<tr>
<td>4</td>
<td>1.60 ± 0.05</td>
<td>2.55 ± 0.15</td>
<td>0.32 ± 0.08</td>
<td>4.08 ± 0.31</td>
</tr>
<tr>
<td>P-value</td>
<td>0.200</td>
<td>0.072</td>
<td>0.904</td>
<td>0.430</td>
</tr>
</tbody>
</table>


Feed and nutrients utilization:

O. niloticus reared in the poly-culture system with silver carp at 8% (T3) revealed the highest values of feed intake (FI, g), protein productive value (PPV), and energy utilization (EU, %) and the differences among all groups were significant (P ≤ 0.05). Also, O. niloticus reared in the poly-culture system with silver carp at 4% (T2) revealed the best (P ≤ 0.05) value of feed conversion ratio (FCR) and the highest (P ≤ 0.05) protein efficiency ratio (PER) among all groups (Figure 2 a, b). Where, the positive effects of T2 and T3 on feed and nutrients utilization confirmed by their superiority effects on the growth performance (Table 4) and body composition (Table 5) of the experimental fish than of O. niloticus reared on mono-culture system (T1) or in poly-culture system with silver carp at 12% (T4).

Poly-culture and/or integrated culture have been widely used in freshwater and marine aquaculture to improve yield and nutrient utilization efficiency (Neori et al., 2004). In this respect, carp poly-culture food inputs used worldwide are whole food items, farm-made aqua foods and commercial balanced food (Tacon and Hasan, 2007). Also, El-Saidy and Gaber (2002) confirmed that mean final weight and length, weight and length gain, SGR, and FCR of O. niloticus were significantly (P ≤ 0.01) the best at the lower stocking density; while, total production and net production
exhibited significantly the opposite trend. Additionally, Kheir and Saad (2003) proved that the least stocking rate attained the highest significant ($P \leq 0.05$) final weight, weight gain, SGR, FCR, and PER for *O. niloticus*. Inversely with the obtained results herein, Adewolu *et al.* (2008) reported that the two species of the Claridi catfish and their hybrid performed best in terms of growth and feed utilization in monoculture than in duo-culture and trio-culture systems. Also, the same conclusion was detected by Abdelhamid (2011) of monosex *O. niloticus* reared in mono-culture system in net cages followed by that of poly-culture for their superiority in feed and nutrients efficiency parameters.

![Fig. 2(a-b): Effect of the experimental mono or poly-culture systems in cages on feed efficiency parameters (a) FI and (b) FCR, PER, PPV, and EU of Oreochromis niloticus](image)

**Total production of *O. niloticus*:**

Although, *O. niloticus* reared in mono-culture system, they gave the highest total production (735 kg) compared to the poly-culture systems, but this treatment (T1) and the poly-culture system with 12% silver carp (T4) gave the lowest total output of *O. niloticus* (6210, and 5820 LE, respectively) compared to the other poly-culture systems with 4% silver carp (T2), and 8% silver carp (T3), which gave the highest total output of tilapia (6590 LE) and (6240 LE), respectively (Table 7). These confusion about the total production and total output of *O. niloticus* reared in different experimental culture systems are related to the difference in their size among all treatments (Table 7). Where, in case of *O. niloticus* reared in poly-culture system with 4% silver carp (T2) and with 8% silver carp recorded the highest size 1 and size 2 of *O. niloticus* than those the size of fish in both T1 and T4, which reflected in increasing the total output of T2 and T3 than of T1 and T4, respectively (Table 7). Economic efficiency (%) parameters:

Intensive production is growing fast and takes two forms. Around 10% of total aquaculture production is from cage culture, principally of Nile tilapia. Fish farmers in rural area sometimes use very small cages suspended in drainage canals (GAFRD, 2012). In the present study, *O. niloticus* reared in poly-culture system with 12% silver carp (T4) gave the highest total output (LE), total profit (LE), and economic efficiency (%) among all the experimental mono (T1) or poly-culture systems with silver carp (T2 and T3, Table 8). Although, the best growth performance and feed efficiency, total output, as well as the differentiation of the size were recorded of monosex *O. niloticus* reared in poly-culture system with 4% and 8% silver carp (T2 and T3, respectively)
compared to those monosex *O. niloticus* reared in poly-culture with silver carp at high rate 12% (T4).

These superiority in economic efficiency parameters of T4 may be potentially related to the addition value of silver carp, which increased by increasing the stocking rate of T4 (12% silver carp) than other experimental aquaculture systems. Where, silver carp can adapt to many different environments and can grow very quickly, as well as they can consume 2 to 3 times their body weight in plankton each day and gained 2.7 g / day when fed a large diet. Because of their large size and voracious appetite, silver carp are able to out-compete many other species of fish (Cremer and Smitherman, 1980). Additionally, Avnimech (1998) reported that poly-culture of species combinations with compatible feeding habits can help in maximizing primary productivity and reducing nutrient discharges. Also, Milstein et al. (2002) suggested that stocking two or more complimentary fish species can increase the maximum standing crop of a pond by allowing a wide range of available food items and the pond volume to be utilized.

Nile tilapia and planktivorous silver carp poly-culture can improve the water quality by grazing down the phytoplankton by the latter species and enhance the growth of former species and their health status. It also helps to gain an extra crop of silver carp without incurring additional cost, making aquaculture more profitable to farmers (Sarkar et al., 2006 and 2008). As the current findings herein, Khouraiba et al. (1991) reported that the poly-culture system of Nile tilapia at ratios of 1:10 and 2:10 for tilapia and common carp in cages, respectively gave higher (30%) total net production than that of tilapia cultured alone in a mono-culture system. Moreover, Essa et al. (2008) revealed that Nile tilapia and silver carp culture in net-enclosures was more productive (12.26 kg / m³ / 5 months) and economic than mono-culture system of Nile tilapia (5.77 kg / m³ / 5 months). Inversely with our findings, Abdelhamid (2011) concluded that the best treatment is the mono-culture of monosex Nile tilapia followed by that of poly-culture with silver carp at high or low stocking densities, regarding to their superiority in growth and feed efficiency, besides the economic efficiency parameters.

<table>
<thead>
<tr>
<th>Treatment (cage)</th>
<th>Size 1</th>
<th>Size 2</th>
<th>Size 3</th>
<th>Size 4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total production (kg)</td>
<td>115</td>
<td>160</td>
<td>310</td>
<td>150</td>
<td>735</td>
</tr>
<tr>
<td>Total production (%)</td>
<td>15.65</td>
<td>21.77</td>
<td>42.18</td>
<td>20.41</td>
<td>100.00</td>
</tr>
<tr>
<td>Total output of tilapia (LE)</td>
<td>1380</td>
<td>1600</td>
<td>2480</td>
<td>750</td>
<td>6210</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total production (kg)</td>
<td>220</td>
<td>190</td>
<td>200</td>
<td>90</td>
<td>700</td>
</tr>
<tr>
<td>Total production (%)</td>
<td>31.43</td>
<td>27.14</td>
<td>28.57</td>
<td>12.86</td>
<td>100.00</td>
</tr>
<tr>
<td>Total output of tilapia (LE)</td>
<td>2640</td>
<td>1900</td>
<td>1600</td>
<td>450</td>
<td>6590</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total production (kg)</td>
<td>170</td>
<td>255</td>
<td>150</td>
<td>90</td>
<td>665</td>
</tr>
<tr>
<td>Total production (%)</td>
<td>25.56</td>
<td>38.35</td>
<td>22.56</td>
<td>13.53</td>
<td>100.00</td>
</tr>
<tr>
<td>Total output of tilapia (LE)</td>
<td>2040</td>
<td>2550</td>
<td>1200</td>
<td>450</td>
<td>6240</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total production (kg)</td>
<td>210</td>
<td>195</td>
<td>125</td>
<td>70</td>
<td>600</td>
</tr>
<tr>
<td>Total production (%)</td>
<td>35.00</td>
<td>32.50</td>
<td>20.83</td>
<td>11.67</td>
<td>100.00</td>
</tr>
<tr>
<td>Total output of tilapia (LE)</td>
<td>2520</td>
<td>1950</td>
<td>1000</td>
<td>350</td>
<td>5820</td>
</tr>
</tbody>
</table>

Size 1: 300 – 500g; Size 2: 200 – 250g; Size 3: 100 – 150g, and Size 4: 50 - 100g.
Table 8: Effect of the experimental mono or poly-culture systems in cages on the economic efficiency (% parameters of each cage

<table>
<thead>
<tr>
<th>Treatment (cage)</th>
<th>Total output of cage (LE)</th>
<th>Total input of cage (LE)</th>
<th>Total profit of cage (LE)</th>
<th>Economic efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6210</td>
<td>4450</td>
<td>1760</td>
<td>39.59</td>
</tr>
<tr>
<td>2</td>
<td>7310</td>
<td>4600</td>
<td>2710</td>
<td>58.98</td>
</tr>
<tr>
<td>3</td>
<td>7680</td>
<td>4715</td>
<td>2965</td>
<td>60.95</td>
</tr>
<tr>
<td>4</td>
<td>7980</td>
<td>4680</td>
<td>3300</td>
<td>70.47</td>
</tr>
</tbody>
</table>

1- Total feed costs per cage (LE / Kg diet) = feed costs per one kg diet × feed intake
2- Total outputs per cage (LE / Kg) = fish price × total fish production*
* Total fish production per cage = final number of fish × fish weight gain
3- Total profit of cage (LE) = total output – total input of cage
4- Economic efficiency per cage (%) = (total profit / total input) × 100

The price of 1 kg ingredient was used in the present study (3.20 LE), as well as the price of fish according to the local market price in Egypt at the time of the study (2013).

CONCLUSION

Based on the biological obtained findings herein, it could be concluded that monosex *O. niloticus* reared with *H. molitrix* at 4% (T2), and 8% (T3) in poly-culture systems are the best aquaculture systems among the experimental mono-culture (T1) system or other poly-culture system with 12% *H. molitrix* (T4). While, from the economic point of view, it could be recommended that *O. niloticus* reared in poly-culture system with 12% silver carp (T4) gave the highest total output, total profit, and economic efficiency parameters among all the experimental mono (T1) or other poly-culture systems with silver carp at 4% (T2) or 8% (T3). Accordingly to the present findings, further studies are required for determination the optimal stocking rate of *O. niloticus* and *H. molitrix* in poly-culture system in cages or in other aquaculture systems with other fish species, or in different feeding sources, levels and percentages…etc.

REFERENCES


**ARABIC SUMMARY**

تأثير نظامي الاستزراع الأحادي أو المتعدد على جودة المياه، أداء النمو والكفاءة الإنتاجية لأسماك البلطيقة والبروتين الغذائي

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هذا الدراسة هدف منها تأثير الإجراءات المتعددة في كلا من التحفيزات (الصفر، ٤٠ و٨٠٪) للأحياء بين البلطيقة والبروتين الغذائي كنظام استزراع أحادي (المعاملة الأولى) أو متعدد (المعاملات الثلاثة، الثلاثة والرابعة على التوالي) لمدة ٢٤ يومًا (٢ شهور) على قياسات جودة المياه ، كفاءة النمو والاستفادة من الغذاء ، معالجات الحالة، تكبير الجسم، تجميع الانتاج الكلي للبلطيقة، الكفاءة الإنتاجية في كل معاملة. أجريت هذه التجربة بشكل مبكر في مختلف بحيرات مصر في بحيرة المنزلة. وُضعت النتائج التي تأثرت الإنتاجية في نظام الاستزراع المتعدد مع البروتين الغذائي مع نظام الاستزراع المتعدد على جودة المياه، أداء النمو والكفاءة الإنتاجية لأسماك البلطيقة. حيث أن استزراع المتعدد للجريس البلطيقة مع معدلات ٤٪ (المعاملة الثانية) أو ٨٪ مبروك فضي (المعاملة الثالثة) كاشف أفضل معنوي من حيث قياسات كفاءة النمو والاستفادة من الغذاء، التكبير، تجميع الانتاج، الاستفادة من البروتين والطاقة، تكبير الجسم (البروتين الخام، الدهون، ومحتوى الطاقة) كنوع من الأسماك. بينما أسماك البلطيقة في المعاملة الثانية كانت أعلى معدل تكبير ٢٪ من البروتين، وتزَمَّنَّت مع معدل تخزين ١٢٪ من البروتين في نظام الاستزراع المتعدد. في بحيرة المنزلة، حيث أن نظام الاستزراع المتعدد للجريس البلطيقة سويق نظام الاستزراع المتعدد في نظام الاستزراع المتعدد (المعاملات الثلاثة). وبالتالي يمكن التوصية بأن بالنسبة للجريس البلطيقة المتعدد، في نظام الاستزراع المتعدد مع معدل تخزين ١٢٪ من البروتين فضي (المعاملة الرابعة) لكل نظام استزراع الغذائي في نظام الاستزراع المتعدد. في النظم التجريبية، كان أفضل نظام استزراع بين كل النظم التجريبية.