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Nighttime Dissolved Oxygen Dynamics Under Different Fertilizer Loads in Green Water Tank Culture

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ABSTRACT

This study was conducted to investigate the effect of medium and high doses of either chemical or organic fertilizers along with supplementary feeding on oxygen budgets in concrete rearing tanks of Nile tilapia. The control treatment received no fertilizer. The experiment lasted 90 days during summer season (2010). Dusk oxygen concentrations were significantly higher in the medium chemical fertilizer and control treatments compared to those of the high fertilizer treatments. This was due to the excessive algal bloom and oxygen cycling in the high fertilizer treatments which is linked to the dissolved oxygen deterioration. Moreover, excessive algal blooms in the high chemical fertilizer (Secchi disk reading = 9.6 cm) and high organic fertilizer (Secchi disk reading = 11.6 cm) treatments led to oxygen cycling and lowered the photosynthetic activities of the dense algal blooms observed in those treatments. In the medium and high organic fertilizer treatments, the average rate of nighttime community respiration (nCR) exceeded that of the daytime net primary production (dNPP) by a factor of about 1.3 – 1.55:1, suggesting net heterotrophy. All other treatments resulted in a positive oxygen budgets with a very low oxygen surplus at daybreak, suggesting net autotrophy. Considering a nighttime period of 10.0 hours during this study, it is not recommended to use a high fertilizer dose along with supplementary feeding due to its negative effect on both oxygen dynamics and fish growth .The medium chemical fertilizer and the control treatments had higher dissolved oxygen content through the nighttime period, higher daytime net primary productivity, moderate algal blooms and better environmental conditions for fish production.

Keywords: chemical fertilizer-organic fertilizer-oxygen budget-algae-Nile tilapia.

INTRODUCTION

Feeding rates vary greatly among fish producers; some producers feed to satiation, while others limit feed to a preset level because of concern about deteriorating water quality (Robinson and Li, 1999). The general perception is that fish cannot be fed to satiation at the end of the growing season when biomass is high because the high level of feed input will deteriorate water quality to a point that production may be reduced (Robinson and Li, 1999).

Inadequate dissolved oxygen and poor water quality are frequently found in ponds receiving organic wastes and can lead to many serious problems for fish culture in ponds. Problems of low dissolved oxygen are particularly prevalent in ponds during the night and early morning when there are large additions of organic wastes and feeds (Boyd,1982; Chang,1986 and Chang, 1989).

Organic matter is constituted by a number of materials such as feces, uneaten feed, organic manure, dead phytoplankton and zooplankton in different decomposing stages, which demand high amounts of oxygen for total decomposition (Fast and Boyd, 1992). Increased accumulation of sediment organic matter could affect pond health through the promotion of anoxic conditions and the production of toxic substances like H_2S (Munsiri *et al*., 1995).

Respiration from decomposition of waste organic matter and dead phytoplankton often exceeds gross photosynthesis (net heterotrophy) in aquatic systems with high rates of allochtonous organic matter input, such as ponds used for wastewater treatment or semi intensive aquaculture (Hargreaves and Tucker, 2003 and Hargreaves, 2006). Moreover, high organic particle concentrations imply high water column respiration rates (Hargreaves, 2006). In catfish ponds, Steeby *et al*. (2004) observed a mean sediment respiration (SR) of 0.48 g O_2 /m^2 /hour. Compared with catfish ponds, sediment respiration in four marine shrimp ponds, averaging 0.6 – 0.9 m in water depth was a greater proportion (52%) of total pond respiration (Madenjian, 1990). Intensive nutrient inputs lead to an abundant community of microorganisms (Ray *et al.*, 2010). Dense growths of algae are found in ponds with major inputs of organic materials (Chang, 1989).

The nutrients derived from organic waste and unused feed enhance algal growth. Dense growth of algae contribute large amounts of DO in ponds during the daylight period, resulting in super-saturation of oxygen in the epilimnion, but consume substantial quantities of oxygen at night causing anoxic conditions in pre-dawn hours (Boyd, 1982) . Guo-cai *et* *al*. (2000) reported that the rate of plankton community respiration was nearly half (49%) of the rate of phytoplankton gross production.

Phytoplankton in some green water systems can fix from 10 to 12 g C/ m^2 /day (Brune *et al*., 2003). Algal densities when ranged from 40 to 60 mg/l dry weight, produce secchi disk readings of 15 to 18 cm. When algal densities reach 100 mg / l dry weight, producing secchi disk readings of 10 cm. This leads to excessive dissolved oxygen cycling and low night –time DO levels (Brune *et al*., 2004).

Hargreaves and Steeby (1999) reported that the assumption that indices of net primary production (NPP) and whole pond respiration (WPR) rates can be derived from linear regression of diurnal and nocturnal segments of diel DO curves was reasonable, as indicated by high coefficients of determination (> 0.90) on most days. The objective of the current study was to evaluate the nighttime oxygen dynamics and growth performance of Nile tilapia under different fertilizer loads in semi-intensive systems.

MATERIALS AND METHODS

The current experiment was conducted at the Fish Research Unit, Faculty of Agriculture, Cairo University in a series of rectangular concrete tanks (2.2 × 1.2 × 1.0 m each). The experiment consisted of two organic fertilizer treatments (medium and high doses), two chemical fertilizer treatments (medium and high doses) and control treatment. The control treatment received no fertilizer during the experiment. Monosex Nile tilapia (average weight = 131.3-137.7 grams/fish) were obtained from Kafr Elsheikh and stocked randomly at 7.0 units per concrete tank in all treatments. The experiment lasted 90 days during summer season, 2010.

All fertilizer treatments received supplementary diet (18 % crude protein) at a fixed rate (6.5 g /m^2 /day) for six days a week during the whole experiment. The control treatment received the application of a complete diet (30 % crude protein) at a fixed rate (6.5 g /m^2 /day), six days a week during the experiment. All diets were formulated and processed at the Fish Research Unit. The chemical fertilizer treatments received a weekly application of chemical fertilizer (ammonium nitrate, 33%N and super-phosphate, 8% P) at medium and high doses (1.0 and 1.5 grams N / m^2 for nitrogen and 0.25 and 0.38 grams P / m^2 for phosphorus, respectively). The organic fertilizer treatments received a weekly application of chicken manure at medium and high doses (14.0 and 28.0 grams dry matter /m^2, respectively) along with the fixed feeding rate. The organic fertilizer (poultry manure) obtained from the Poultry Production Unit ,was sun dried and contained 3.87 % N and 4.18 % P_2O_5. The experiment included five treatments, with duplicate tanks per treatment**.**

Water quality parameters

All determinations of water quality parameters were carried out in the Fish Research Unit (Faculty of Agriculture, Cairo University). Water temperature and dissolved oxygen were measured using HANNA Instrument (model 55) dissolved oxygen meter. Readings of dissolved oxygen were taken by integrating the probe of oxygen meter over the whole depth of water (80 cm) up to the bottom of the tank. Estimates of secchi disk visibility were taken at the same day along with oxygen and pH readings. The pH was measured by a pH digital meter at the laboratory after collection of the representative sample.

Oxygen dynamics

Calculations that predict nighttime decline in DO were based on Boyd *et al*. (1978) and Romaire and Boyd (1979). The projection method was based on assuming that the DO decline during nighttime is essentially linear with respect to time. When DO concentration at dusk and nighttime are plotted versus time, a straight line through the two points was projected to estimate DO at dawn or at other times during night. Boyd (1998) confirmed the high accuracy of the projection method in predicting DO concentration at dawn compared with measured values. Romaire and Boyd (1979) indicated that the nighttime dissolved oxygen model gave highly reliable prediction of early morning DO concentration. An additional simplifying assumption was made not to correct daytime net primary production (dNPP) or nighttime community respiration (nCR) for diffusion according to Hargreaves and Steeby (1999).

Dissolved oxygen data were analyzed to calculate the duration (hours) that DO concentrations were less than 1.0 mg /l or near zero oxygen in the per-dawn hours. Determination of daytime net primary production and nighttime community respiration required the measurements of dissolved oxygen. Water temperature was measured at dusk while DO and pH were measured three times daily (early morning at 07: 00 a.m., dusk at 08:00 p.m. and nighttime at 00: 00 h). The duration of nighttime hours (from dusk to dawn) during the last month of the experiment was approximately 10 hours while the daytime period lasted 14 hours. All the following formulas were models made by the authers and derived from Boyd *et al*. (1978), Romaire and Boyd (1979), Szyper (1996), Boyd (1998) and Hargreaves and Steeby (1999).

Oxygen dynamics parameters

Nighttime community respiration per hour ($nCRh^{-1}$) = (dusk oxygen concentration –midnight time oxygen concentration) /4.

Optimal nighttime community respiration (nCR) = hourly measured nighttime community respiration × nighttime duration (10 hours).

Daytime net primary production (dNPP) = dusk oxygen concentration – dawn oxygen concentration.

Dawn oxygen surplus or deficit = dusk DO concentration – nCR.

Optimal nighttime community respiration: daytime net primary production (nCR : dNPP ratio) = nCR / dNPP.

Duration of oxygen supply after dusk (above 1.0 mg/l)=

Duration (hours : minutes) of oxygen concentration before dawn below 1.0 g oxygen/m^2 = [(dusk DO concentration -1) / $nCRh^{-1}$]-10.

Gross photosynthesis

Averages of algal gross photosynthesis were calculated according to Lind (1979) as follows: Average algal gross photosynthesis (g C/m^3 /day) = (Net daytime production of dissolved oxygen dNPP + daytime community respiration) × 0.375. Assuming that nighttime respiration per hour was equal to daytime respiration per hour, the daytime community respiration was calculated as a function nighttime respiration rate per hour and the number of hours in a daytime period.

Statistical analysis

Water quality parameters in culture tanks were subjected to one – way analysis of variance to determine significant statistical differences among treatments. Differences among means were assessed by Duncan multiple range test (Duncan, 1955). Statistically significant differences were determined by setting the aggregate type I error at 5% for each comparison. These statistical analyses were performed using the software package SPSS for windows, Release 8.0 (SPSS, 1997).

RESULTS

Oxygen concentration at dawn, dusk and midnight

Oxygen concentrations at dusk in experimental tanks are shown in Table 1. Dusk oxygen concentrations were significantly higher in the medium chemical fertilizer and control treatments (11.01 – 11.03 g O_2/m^2) compared to those of the high chemical fertilizer and organic fertilizer treatments (6.87-8.87 g O_2/m^2).This was due to the excessive algal bloom and oxygen cycling in the high chemical fertilizer treatments which was linked to dissolved oxygen deterioration (Boyd, 1990). The lower oxygen concentration at dusk in the manure treatments were due to the biological oxygen demand needed for manure decomposition by bacterial activities and the lower efficiency of the organic fertilizer in terms of enhancing oxygen production through photosynthesis. Better oxygen production in the control treatment was linked to the high protein content of the diet (30% crude protein), accompanied by the excretion of metabolic ammonia and phosphate by fish, through dietary protein metabolism. These nutrients enhanced algal productivity and oxygen production.

Table (1). ***Oxygen dynamics under different fertilizer loads in green water tank culture.***

Treatment Parameter	Chemical Fertilizer		Organic Fertilizer		Control 30% C.P.
	Medium	High	Medium	High	
Dusk oxygen concentration (gO_2/m^2)	**11.01 a**	**8.87 b**	**8.32 bc**	**6.87 c**	**11.03 a**
Midnight oxygen concentration (g O_2/m^2)	**6.77 a**	**5.39 b**	**4.08 c**	**2.63 d**	**6.95 a**
Daytime net primary production (dNNP - g O_2/m^2/daytime)	**10.62 a**	**7.99 ab**	**8.23 ab**	**6.87 b**	**10.25 a**
Nighttime community respiration/ hour ($nCRh^{-1}$ - g O_2/m^2/hour)	**1.06 a**	**0.87 b**	**1.06 a**	**1.06 a**	**1.02 a**
Optimal nighttime community respiration (nCR - g O_2/m^2/nighttime)	**10.62 a**	**8.73 a**	**10.62 a**	**10.68 a**	**10.25 a**
Dawn oxygen surplus /deficit ($\pm$ g O_2/m^2)	**+ 0.379 a**	**0.145 a**	**-2.293 b**	**-3.812 b**	**+ 0.786 a**

Means in the same row with different letters are significantly different (P < 0.05)

During daytime, the pond DO concentration increases as the phytoplankton produce more oxygen through photosynthesis than is consumed through respiration and decay (Ghosh and Tiwari, 2008). The relation between oxygen production and consumption with the increase in Chlorophyll-a concentration showed that the production and consumption of oxygen were linearly correlated with the increase in Chl-a concentration (Ghosh and Tiwari, 2008). Kayombo et al. (2000) obtained a rate of DO production 1.59 mg /mg of dry algal biomass in waste stabilization pond.

Excess chemical fertilization resulted in excessive algal blooms which sedimented continually to the bottom of the tanks in the forms of dying and dead algae. Consequently, resulting in an accumulation of organic material (dead algal matter) at the bottom sediment. This resulted in a decrease of dusk oxygen concentration due to the active decomposition of dead algae by bacteria during daytime hours, with a higher bacterial oxygen demand. Excess organic fertilization always results in a similar process.

Respiration resulting from the decomposition of waste organic matter and dead phytoplankton often exceeds gross photosynthesis in aquatic systems with high rates of allochtonous organic matter input, such as ponds used for wastewater treatment or semi-intensive aquaculture (Hargreaves, 2006). Smith and Piedrahita (1988) reported that the intermediate phytoplankton densities (150-350 µg Chl a/l) will maximize oxygen production.

Constant community respiration (g O_2/m^2 /hr) during nighttime hours was assumed in order to estimate the duration that DO concentration was above 1.0 mg/l according to Steeby *et al.* (2004) and Boyd *et al*. (1978). The value above 1.0 mg/l was used since tilapia can withstand this concentration, without adverse effects on growth performance.

The average dissolved oxygen concentrations at midnight were significantly lower ($P < 0.05$) in treatments receiving the high chemical fertilizer (5.39 g O_2/m^2) and organic fertilizers (2.63 – 4.08 g O_2/m^2) compared with those receiving the medium chemical fertilizer and control treatments (6.77-6.95 g O_2/m^2). The decrease in DO at dusk in the organic fertilizer treatments was due to the daytime bacterial oxygen demand needed for manure decomposition and the presence of excess of organic load (6.5 grams feed plus 2-4 g dry manure /m^2/day) above the waste assimilative capacity of water and sediment. The medium chemical fertilizer and control treatments had just the correct feed load (6.5 g/m^2/day) that exactly matched the waste assimilative capacity of water and sediment, resulting in a slightly positive oxygen budget at dawn. The decrease in dusk oxygen concentration in the high chemical fertilizer treatment was due to the presence of dense low quality algal bloom (Secchi disk reading = 9.6 cm) which had lower photosynthetic activity under the dense bloom during daylight hours, resulting in low DO concentration at both dusk and midnight times.

Hypertrophic aquatic systems are characterized by a wide gap in DO concentration between dusk and daybreak times (Barica, 1980). Maximum DO concentration in earthen ponds is expected at dusk, while minimum DO concentration is expected at daybreak. In the current study, DO at daybreak ranged 0.145 - 0.78 g O_2/m^2 in the chemical fertilizer and control treatments, while DO at dusk ranged 8.87 -11.03 g O_2/m^2. The gap in DO concentration between dusk and daybreak among those treatments ranged 8.73 to 10.25 g O_2/m^2, which indicated a high oxygen reserve available at dusk for nighttime respiration. Chang and Ouyang (1988) reported that the maximum gap in DO between day and night in a 24 hours period was as great as 10 g /l Tucker (2003) indicated that dissolved oxygen concentration at sunset could be enhanced through moderate algal blooms which increase the capacity of water to assimilate organic matter through aerobic processes, consequently, the capacity of ponds to assimilate organic matter by aerobic processes increases.

Daytime net primary production (dNPP) and optimal nighttime community respiration (nCR

Szyper (1996) indicated that the total daily areal oxygen production during daylight hours can be calculated in the free water on areal (water column) basis which has the dimensions of g O_2 /m^2/day. Daytime net areal primary production rates (dNNP= g O_2 /m^2/ day) were calculated in the current study according to the free water sampling (Szyper, 1996). Nighttime community respiration (nCR) rates were estimated from a straight line interpolation over 4-hour period during early nighttime period.

During daylight hours, photosynthesis leads to an increase in the amount of oxygen (Mukherjee *et al*., 2008). Supersaturated values as high as 180% in the sea and 300% in freshwaters have been reported (Clarke, 1969).

Loss of oxygen from fish pond is due to fish respiration, plankton respiration, water column respiration and sediment respiration (Ghosh and Tiwari, 2008). Losordo (1980) found that water column respiration accounted for on average about 60% of the overnight DO decrease in the Auburn pond, which could be attributed to the plankton respiration rate.

The dawn oxygen deficits observed in the high organic and high chemical fertilizer treatments were caused by their lower daytime net primary production (dNPP = 6.87-8.23 g O_2/m^2/daytime) compared to those of the control and medium chemical fertilizer treatments (10.25-10.62 g O_2/m^2/daytime). The organic fertilizer had a lower efficiency in terms of enhancing the dNPP compared to that of the chemical fertilizer. This is in accordance with Knud-Hansen *et al*. (1993) who reported that chicken manure P was about 10% effective as TSP-P at increasing primary productivity. Moreover, because of its low N and P contents and high oxygen consumption, organic fertilizer alone is unlikely to provide adequate nutrients for algal photosynthesis and sufficient oxygen for fish (Qin *et al.*, 1995).

Photosynthesis supplies most of the oxygen to meet respiratory demand, although most of the oxygen produced in photosynthesis is consumed by phytoplankton respiration (Hargreaves and Tucker, 2003). Analysis of data consisting of dissolved oxygen concentration measurements recorded every 15 minutes in three commercial catfish ponds, indicated that reaeration was not an important contributor of oxygen until pond dissolved oxygen concentrations declined to less than 2.0 mg/l (Hargreaves and Steeby, 1999).

In the current study, excessive algal blooms in the high chemical fertilizer (Secchi disk = 9.6 cm) and high organic fertilizer (Secchi disk = 11.6 cm) treatments led to oxygen cycling and lowered the photosynthetic activities and oxygen production by the dense algal blooms observed in these treatments (Table 2).

Guo-cai *et al*. (2000) reported that the rate of plankton community respiration was nearly half (49%) of the rate of phytoplankton gross production. Moreover, water column respiration accounted for an average of 68% (range: 53-76%) of whole pond respiration (WPR) in two tropical fish ponds when water temperature was >28 ˚C (Teichert-Coddington and Green, 1993).

Under excessive algal blooms as observed in the high chemical fertilizer treatment (Secchi disk = 9.6 cm), a large proportion of the water column was a net consumer of oxygen because the photic zone of water with dense bloom was very shallow (≈ 25cm). Consequently, the deeper dark zone full of dying algae and organic matter was a net consumer of oxygen (Table 2).

Oxygen production by algal photosynthesis increases the oxygen content of water during daylight hours (dNPP) while the nighttime community respiration including decomposition by aerobic bacteria (nCR) decrease oxygen content of water during nighttime hours. In the medium and high organic fertilizer treatments, the average nighttime community respiration (nCR= 8.73-10.68 g O_2/m^2/

per nighttime) exceeded the daytime net primary production (dNPP = 6.87-8.23 g O_2/m^2 per daytime) by a factor of about 1.3–1.55:1, suggesting net heterotrophy, with a duration of less than 1.0 g /m^2 depleted oxygen that ranged from 03:06 to 04:32 hours before daybreak. All other treatments resulted in positive oxygen budgets with low oxygen surpluses at daybreak (0.145 – 0.379 g O_2/m^2 at daybreak), suggesting net autotrophy.

In a pond, dissolved oxygen concentration depends on the balance between photosynthetic production, total respiration and exchanges with atmosphere (Ghosh and Tiwari, 2008). According to Boyd (1990), algae produce most of the oxygen by photosynthesis and consume most of the oxygen through phytoplankton respiration. As a result, excessive algal blooms adversely affected oxygen budget. Nighttime community respiration (water column and sediment respiration) ranged 1.02 – 1.06 g O_2/m^2 /hour among treatments, except for the high chemical fertilizer treatment which had a lower nighttime community respiration (nCR= 0.87 g O_2/m^2 /hour) due to its dense bloom of low quality algae.

Table (2). ***Oxygen dynamics and water quality under different fertilizer loads in green water tank culture.***

Treatment Parameter	Chemical Fertilizer		Organic Fertilizer		Control 30% C.P.
	Medium	High	Medium	High	
Duration of oxygen supply below 1.0 gram oxygen/ m^2 (hours)	**00:35**	**00:58**	**03:06**	**04:32**	**00:12**
nCR : dNNP ratio	**1.07 c**	**1.08 c**	**1.3 b**	**1.55 a**	**1.05 c**
Gross primary production(g O_2 /m^2/day)	**25.88**	**21.09**	**23.19**	**21.81**	**25.38**
Optimal Community respiration per day (g O_2 /m^2/day)	**25.44**	**20.88**	**25.44**	**25.44**	**24.48**
Gross primary production(g carbon /m^2/day)	**9.73**	**7.93**	**8.72**	**8.2**	**9.54**
Secchi disk readings (cm)	**15.5 a**	**9.6 b**	**15.1 a**	**11.6 b**	**15.3 a**
Water temperature (^oC)	**30.8 b**	**30.0 c**	**30.8 b**	**30.8 b**	**31.6 a**

Means in the same row with different letters are significantly different (P < 0.05).

As nutrient availability and total phosphorus increased, bacteria accounted for a decreasing amount of plankton community respiration while, heterotrophic bacteria often account for as much as 20% in eutrophic systems (Roberts and Howarth, 2006). Most studies of oxygen budgets in hyper-eutrophic aquaculture ponds indicate the overwhelming contribution of phytoplankton respiration to nighttime oxygen depletion (Smith and Piedrahita, 1988 and Teichert-Coddington and Green, 1993).

In the medium fertilizer and control treatments, the average daytime net oxygen production (dNPP =10.25 - 10.62 g O_2/m^2 /daytime) equaled the nighttime community respiration (nCR =10.25 -10.62 g O_2/m^2/ nighttime), which suggested slight net autotrophy where feed and fertilizer loadings were just equal to the waste assimilative capacity of water and sediment in terms of the net amount of daytime oxygen production (g O_2/m^2/day).This oxygen production was needed to oxidize all organic matter inputs (*i.e.*, dead algae and feed) during the process of bacterial and fish metabolism. In the organic fertilizer treatments, the extra manure load (2-4 g/m^2/day) above the feed input (6.5 g/m^2 /day), resulted in oxygen deficit before daybreak, suggesting that feeding rate at 6.5 g/m^2/day was the maximum feed load limit that just equaled the assimilative capacity of water in terms of oxygen availability needed for the oxidative metabolism .

1. *Oxygen budget at dawn*

Although the high chemical fertilizer treatment had positive oxygen budget (oxygen surplus at dawn = + 0.145 g O_2/m^2), the oxygen surplus was lower compared with that of the control treatment (+ 0.78 g O_2/m^2), where no fertilizer was applied. The high chemical fertilizer treatment should have higher detrital organic matter (dead algae) sedimentation to the bottom sediment in the concrete tanks due to its excessive algal bloom (secchi disk = 9.6 cm) compared to that of the control treatment (secchi disk =15.3 cm). Concequently, the increase in algal load (suspended algae) in the high chemical and high organic fertilizer treatments led to a decrease in the amount of DO available at daybreak. While the control treatment did not receive any fertilizer, therefore, the algal load (Secchi disk =15.3 cm) was lower compared to other fertilizer treatments. The control treatment had a reduced bacterial oxygen demand (sediment respiration) and led to the increase in the amount of oxygen available at daybreak (a higher oxygen surplus).

Dawn oxygen surpluses were observed in the chemical fertilizer and control treatments (0.379, 0.145 and 0.786 g O_2/m^2, respectively), indicating net autotrophy and surplus oxygen concentration at daybreak. However, dawn oxygen deficits were observed in the organic fertilizer treatments (-2.29 and -3.81 g O_2/m^2), indicating net heterotrophy and near zero oxygen concentration in the per-dawn hours.

Adding an additional organic fertilizer load (2-4 g dry chicken manure $/m^2$/day) in the organic fertilizer treatments along with the daily fixed feed load (6.5 g/m^2), resulted in a negative oxygen budget at dawn (-2.29 to – 3.81 g O_2/m^2), which was proportional to the amount of organic fertilizer . In this case, water during the pre-dawn period were aerated with oxygen through diffusion caused by wind action at the air-water interface for several hours, with minute amount of oxygen available for fish survival. This indicated that the loading limit of organic matter as feed should not exceed 6.5 g dry matter $/m^2$/day in order to reach a steady–state sustainable positive oxygen budget at dawn, without exceeding the waste assimilative capacity of static water.

2. Dense algal bloom and oxygen budget

Excessive algal bloom and higher dead algae load at the bottom sediment affected the waste assimilative capacity of static water since most of the oxygen content in static water is consumed by phytoplankton respiration (Hargreaves and Tucker, 2003). Dense algal load in the water column negatively affected oxygen budget. Most of the variation in daytime net primary productivity (dNPP as g O_2 $/m^2$/day) among treatments was explained the by the secchi disc visibility as an index of phytoplankton abundance. The high chemical and high organic fertilizer treatments had excessive algal bloom (secchi disc = 9.6 – 11.6 cm) and lower daytime net primary productively (dNPP = 6.87 -7.99 g O_2/m^2/day) compared with those of the medium chemical fertilizer and control treatments (Secchi disc = 15.3 – 15.5 cm and dNPP = 10.25 -10.62 g O_2 $/m^2/$ day). The medium chemical fertilizer and control treatments had a deeper photic zone and a higher daytime net primary production.

3. Optimal nighttime community respiration to daytime net primary production (nCR: dNPP ratio)

Large nCR: dNPP ratios (optimal community respiration during night hours: actual daytime net primary production) were observed in the organic fertilizer treatments (1.3–1.55:1) during nighttime which indicated that dissolved oxygen was depleted in the per–dawn hours (Table 2).When the nCR: dNPP ratio is more than 1.0, net heterotrophy in the per –dawn hours is evident. Net heterotrophy in tanks or ponds is observed when large amount of manure or artificial feed are put into them. This was indicated by the community respiration (CR) to Gross Primary Productivity ratio (GPP) parameter. Guo-cai *et al*. (2000) indicated that large CR: GPP ratios (more than 1.0) leads to depletion of dissolved oxygen before dawn, while small CR: GPP ratio (less than 1.0) indicates surplus oxygen at dawn. Brune *et al*. (2003) reported that high rate mixed ponds can yield 26.6-31.9 g O_2/m^2/day or 10-12 g carbon /m^2/day. In the current experiment, gross primary production in terms of daily oxygen and carbon production ranged 21.0 to 25.8 g O_2/m^2 /day and 7.93 to 9.73 g C/m^2 /day, respectively among treatments. Secchi disc depth was progressively reduced over time during the culture period in all treatments, with significant differences among means ($p < 0.05$).The optimal nighttime community respiration (nCR) to daytime net primary production ratio (nCR: dNPP) ranged 1.05-1.55 among treatments .The nCR: dNPP ratios in the medium chemical fertilizer and control treatments (1.05-1.07:1) indicated slight net autotrophy at dawn, while those of the organic fertilizer treatments (1.3 -1.55) indicated net heterotrophy, with dissolved oxygen depletion in the pre-dawn hours. Hargreaves (2006) reported that photosynthesis and respiration of phytoplankton dominate oxygen dynamics and nutrient cycling.

4. *The duration of depleted oxygen*

The duration (hours: minutes) of DO concentration of less than 1.0 mg /l before daybreak differed among treatments. The duration (hours) of DO less than 1.0 mg/l before daybreak was longest in the high organic fertilizer (04:32 hours), intermediate in the medium organic fertilizer (03:06 hours) and shorter in the high chemical fertilizer treatments (00: 58 minutes).

The medium chemical fertilizer and control treatments suffered oxygen deficiency below 1.0 g O_2/m^2 for only 12-35 minutes before daybreak .While the organic fertilizer treatments had higher organic matter loadings in the form of manure, the tanks that received the high chemical fertilizer had a high organic matter loading in the forms of suspended and sedimented algae during the growing season. This suggested that these treatments were hyper-eutrophic as indicated by Hargreaves and Steeby (1999).

The increase in phytoplankton community biomass should result in a corresponding increase in the total amount of respiration being carried out by the phytoplankton community (Roberts and Howarth, 2006). This is consistent with the notion of bacteria utilizing excreted dissolved organic carbon (DOC) from phytoplankton as a carbon source during P-saturated conditions (Roberts and Howarth, 2006).

CONCLUSION

Torrans (2004) indicated that although visible signs of oxygen stress were never observed in the low oxygen treatment, feed consumption was reduced by 45 percent, and average fish weight in the low oxygen treatment was 30 percent less than the control. Net production was also cut in half (Torrans, 2004).This indicates why the high feed load treatments did not have good performance under negative oxygen budget.

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ديناميكية الأكسجين الذائب أثناء الليل تحت جرعات مختلفة من السماد فى نظام أحواض المياه الخضراء.

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أجريت هذه الدراسة لبحث تأثير التغذية التكميلية مع استخدام التسميد العضوي أو المعدني (بجرعتين متوسطة ومرتفعة) على ميزانية الأكسجين فى أحواض البلطي النيلي. استمرت الدراسة 90 يوم خلال فصل الصيف (2010). ارتفع تركيز الأكسجين فى المياه عند غروب الشمس فى معاملة التسميد الكيميائي المتوسط ومعاملة الكنترول بالمقارنة بمعاملات التسميد المرتفعة (مستوى معنوية 0.05). ويرجع هذا إلى ازدهار الطحالب المفرط وحدوث تدوير للأكسجين فى معاملات التسميد المرتفع مما أدى إلى تدهور تركيز الأكسجين الذائب. بالإضافة إلى ذلك فإن ازدهار الطحالب المفرط فى معاملة التسميد الكيميائي المرتفع (قراءة قرص سيكي = 9.6 سم) ومعاملة التسميد العضوي المرتفع (قراءة قرص سيكي = 11.6 سم) أدى إلى تدوير الأكسجين وانخفاض نشاط التمثيل الضوئي للطحالب الكثيفة المزدهرة فى هذه المعاملات. وعند مقارنة معدل التنفس أثناء الليل وكمية الزيادة الصافية فى انتاج الأكسجين أثناء النهار اتضح ارتفاع متوسط استهلاك الأكسجين المستخدم فى تنفس الكائنات المائية أثناء الليل بالمقارنة بالزيادة الصافية فى تركيز الأكسجين عند غروب الشمس فى معاملات التسميد العضوي المتوسط والتسميد العضوي المرتفع بمقدار يتراوح بين 1.3 إلى 1.55 : 1. وهذا يدل على عجز ميزانية الأكسجين الكلية على مدار اليوم. أما باقي المعاملات كانت ميزانية أكسجين موجبة وهذا يدل على أن كمية الأكسجين المتوفرة فى الأحواض عند غروب الشمس كانت كافية لتنفس الكائنات المائية أثناء الليل مع وجود زيادة طفيفة فى تركيز الاكسجين عند الفجر. وخلال هذه الدراسة استمرت فترة الاظلام لمدة 10 ساعات خلال الليل. لذلك ينصح بعدم استخدام التسميد بجرعات مرتفعة عند التغذية بالعلائق التكميلية نظرًا للتأثير السلبي للتسميد المرتفع على ديناميكية الأكسجين. أما بالنسبة لبيئة معاملات التسميد المتوسط والكنترول فقد كانت تركيزات الأكسجين مرتفعة خلال فترة الليل وتراكمت كمية كبيرة من الأكسجين فى المياه عند غروب الشمس و ازدهرت الطحالب بدرجة متوسطة مما أدى إلى توافر بيئة جيدة لنمو الأسماك.

الكلمات الدالة : السماد الكيميائي – السماد العضوي – ميزانية الأكسجين – الطحالب – البلطي النيلي