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Effect of Different Doses of Inorganic Fertilizer on Water Quality, Primary Productivity and Production of Nile Tilapia (*Oreochromis niloticus*) in Earthen Ponds

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تأثير استخدام جرعات مختلفة من السماد الغير عضوي على خصائص المياه والإنتاجية الأولية وإنتاجية البلطي النيلي في أحواض ترابية

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تمت هذه الدراسة بغرض تقييم استخدام جرعات مختلفة من السماد الغير عضوي (٢٠/٢٠/٥ NPK) في أحواض ترابية بالعباسة، تم استزراع ١٥٠ سمكة بلطي نيلي (٢٥-٣٠جم) في كل حوض ويضاف السماد بمعدل صفر و٢٠ و٤٠ و٦٠ و١٠٠ كجم للفدان كل شهر. لم تظهر النتائج وجود اختلافات معنوية في درجة الحرارة والأكسجين الذائب ودرجة الأس الهيدروجيني والأمونيا الحرة ودرجة التوصيل الكهربي وتركيز النترات والقاعدية الكلية والعسر الكلي نتيجة تأثير الجرعات المختلفة من السماد المستخدم بينما كانت الاختلافات معنوية في كل من شفافية المياه وتركيز الفوسفات والنتروجين الكلي. كذلك كان الاختلاف معنوي في متوسط محتوى الكلوروفيل (أ) الذي بلغ أعلى قيمة عند ١٠٠ كجم للفدان كل شهر، كانت أفضل إنتاجية للبلطي النيلي عند استخدام ٦٠ كجم للفدان كل شهر. لذلك ينصح باستخدام ٦٠ كجم للفدان كل شهر من السماد الغير عضوي (٢٠/٢٠/٥ NPK) في مزارع البلطي النيلي.

Key Words : *Abbassa fishponds, carcass chemical composition, chlorophyll 'a', inorganic fertilizer, fish growth, Nile tilapia, water physico-chemistry.*

ABSTRACT

Earthen ponds (surface area 155 m^2 each) were used to study the effect of different doses of inorganic fertilizer on water quality and fish production. Each pond was stocked with 150 fish of Nile tilapia; *Oreochromis niloticus* (25-30 g/fish). The ponds received inorganic fertilizer (20:20:5 NPK) with doses of 0, 20, 40, 60 and 100 kg/acre/month. The obtained results revealed that fertilization had no significant effect on water temperature, dissolved oxygen, pH value, free ammonia water conductivity, nitrate concentration, total hardness, and total alkalinity. Only Secchi disk reading, orthophosphate concentration and total nitrogen were significantly affected by the same treatments. Chlorophyll 'a' content over all the rearing period was increased upon increasing the applied doses and the highest was obtained at the 100 kg/acre/month dose. The production of Nile tilapia is optimum at the 60-kg dose. Data of carcass proximate analyses on fish showed that there were no significant differences in dry matter, while crude protein, total lipids and ash contents were significantly affected by different doses.

Introduction

In Egypt, tilapias are widespread in the Nile River and its attributes as well as in the lakes. Nile tilapia species (*Oreochromis niloticus* L.) is an important food fish and it seems to be the most suitable species for fish farming, where it is extensively cultured in several countries in the world.

The productivity of natural food should be taken into account in tilapia farms. Tilapias in general are herbivores and detritivores, although they show ontogenetic shifts from zooplankton at young ages to phytoplankton, macrophytes, and detritus at advanced ages (Tudorancea *et al.,* 1988; Northcott *et al.* 1991; Abdel-Tawwab, 2000). The wide dietary breadth could have made it a more adaptable species in eutrophic environment (Kaufman, 1992; Hecky, 1993; Gophen *et al.*, 1993).

Inorganic fertilizers are usually added to fish ponds to stimulate and maintain the production of natural food needed for fish growth i.e. increase the population and density of phytoplankton and zooplankton. However, the increase in fish productivity in fertilized ponds has been attributed to increased primary productivity (Almazan and Boyd, 1978; Boyd, 1990; Diana *et al.*, 1991; El-Ayouty *et al.*, 1994). Subsequently, the increase in nutrients budget would increase the primary productivity that would be turned to increase fish production (Batterson *et al.*, 1989; Diana *et al.*, 1991).

Inorganic fertilizer has been promoted as favorable due to its lower loading rates, higher nutrient content and lower oxygen demand (Yamada, 1986; Colman and Edwards, 1987). In Abbassa fishponds, Abdel-Tawwab *et al.* (2002) compared inorganic fertilizers with different NPK ratios, and found that the ratio 20:20:5 NPK produced the highest yield of Nile tilapia. Herein, we studied the proper dose of inorganic fertilizer (20:20:5 NPK) that could be applied to produce the optimum yield of Nile tilapia (*O. niloticus* L.) in Abbassa earthen fishponds, Egypt.

Materials and Methods

1. Pond management and fish culture

Ten earthen ponds (surface area 155 m^2 each) at Central Laboratory of Aquaculture Research, Abbassa, Sharqia Governorate, Egypt were used in this study. The ponds have been drained, cleaned and refilled with new freshwater from El-Wadi canal derived from El-Ismailia canal. The water level was adjusted at 80cm depth. The experiment started on July 3rd 1991 and continued for 126 days.

The ponds were randomly assigned for four levels of fertilizer treatment in duplicate. The ingredients sources were urea (46.5% N; Abo-Qeer Fertilizer Co., Alexandria, Egypt), monosuperphosphate (15.5% P_2O_5); Talkha Fertilizer Co., Mansoura, Egypt) and potassium chloride (63.1% K_2O; El-Nasr Co. for Chemicals, Abu-Zaabal, Egypt). These sources were used to prepare the ratio of 20:20:5 N:P:K. The fertilizers were weekly applied to the ponds at a rate of 0, 20, 40, 60 or 100 kg/acre/month where they were dissolved in 50-liter plastic container and splashed on the water surface of fishpond.

Cultured fish were obtained from the nursery ponds and acclimatized in indoor tanks for 15 days. Fifty fish were frozen at -20°C for initial chemical analyses. To each pond, 150 fish of Nile tilapia; *Oreochromis niloticus* L. (25-30 g each) were stocked. Twenty-five fish from each pond were sampled biweekly using pure seines and individual weight was measured. At the end of the experiment, the ponds were drained and fish were harvested, counted and weighed. Fish samples were subjected to proximate chemical analyses according to the methods of A.O.A.C. (1990) for the determination of moisture, protein, fat and ash.

2. Analysis of water physico-chemical parameters

Water samples for chemical analyses were collected biweekly by a 90-cm water sampler between 08:30 and 09:30 at 30 cm depth from each pond. Dissolved oxygen and temperature were measured on site at 30cm depth with a YSI model 58 oxygen meter (Yellow Spring Instrument Co., Yellow Springs, Ohio, USA) and water conductivity was measured with a YSI model 33 conductivity meter (Yellow Spring Instrument Co., Yellow Springs, Ohio, USA). The pH value and ammonia were measured using Hach kits (Hach Co., Loveland, Colorado, USA). The chemical parameters were analyzed as described by Boyd (1984).

For determination of chlorophyll 'a' content, 100ml of water sample was filtered throughout Millipore acetyl cellulose filter (0.45μm) and the filtered residue was extracted with 90% acetone and measured spectrophotometrically according to Boyd (1984). At the same time, water samples (1 liter bottle) were collected for phytoplankton determination at the same depth and preserved with 4% neutral formalin. Samples were allowed to settle for 15 days and the supernatant was siphoned to 50ml. The counts of phytoplankton were performed using Sedgwick-Rafter cell under a binocular microscope using suitable magnification.

3. Statistical analysis

Water quality data sets were analyzed among treatment levels with Kruskal-Wallis one-way analysis of variance on ranks (ANOVA), using dates as blocks to determine significant differences. Mean separations were determined using Tukey's Test to determine which treatment had greater values. Fish productivity data were compared with ANOVA and differences at the 5% probability level with Duncan's test. Bivariate correlations, stepwise regression and all statistical analyses were conducted with SPSS software program ver 8 as described by Dytham (1999).

Results

1. Physico-chemical parameters

Results in Table 1 showed the mean values of different parameters of water quality in ponds that received different doses of inorganic fertilizer. Table 1 also showed that there were no significant differences in water temperature, which was approximately similar (25.5-25.7°C) and ranged from 21.8 to 28.3°C in all ponds. The mean pH values were approximately similar (8.1) and ranged from 7.9 to 8.7. Water conductivity was only lower in control pond (0.42 mMohs/cm) than the fertilized ponds, which ranged from 0.47 to 0.52 mMohs/cm. Total alkalinity showed insignificant differences among different levels treatment exceeding 200mg/L in all ponds. Total hardness data of pond's water were high with mean values >150mg/L (Fig 1).

Secchi disk visibility was inversely affected by increasing fertilizer doses ($r = -0.569$; $P<0.05$). The maximum mean value was obtained at control ponds (20.7 cm), while the lowest ones were obtained at the 60 and 100 kg doses (17.0 and 17.1 cm, respectively; $P>0.05$). Dissolved oxygen was significantly affected by fertilizer doses ($r = 0.146$; $P>0.05$), and it increased by increasing rearing period ranged from 3.13 to 6.95 mg/L in all ponds with mean value over the time >4.0 mg/L. Orthophosphate concentrations gradually increased with increasing the fertilizer dose ($r = 0.816$; $P<0.05$). The mean values of orthophosphate at control, 20 and 40 kg/acre/month were insignificantly differed (0.361, 0.571 and 0.753 mg/L, respectively), while the highest ones were obtained at the 60 and 100 kg doses (1.306 and 1.363 mg/L, respectively).

The mean values of Nitrate were insignificantly changed with changing the fertilizer dose ($r = 0.271$; $P>0.05$), and the mean values were ranged from 10.91 to 17.62 mg/L. On the other hand, total nitrogen contents were significantly affected by fertilizer doses ($P<0.05$), and the higher values were obtained in fertilized ponds (7.14 to 8.55 mg/L), while the least one was obtained in the control pond (6.14 mg/L; Fig 3).

2. Chlorophyll a content

Results in Fig. 4 indicate that chlorophyll 'a' content in fishpond was increased with increasing the applied doses ($r = 0.65$) and reached the maximum at 100 kg/acre/month. The maximum value of chlorophyll 'a' content in fishpond was obtained in October at the 100-kg/acre/month dose (93.9 μg/L) and the least value was obtained in October at control ponds (37.5 μg/L).

3. Fish production

Application of different doses of inorganic fertilizer (20:20:5 NPK) led to subsequent increase in fish growth ($r = 0.563$) where the maximum growth was obtained at 60 kg/acre/month (Fig. 5). Fish production from adult and fry forms (Fig. 6) shows that total fish production and its constituents were increased with increasing fertilizer dose with the maximum yield at 100 kg/acre/month dose, except for the adult form which was maximized at 60 kg/acre/month dose. The lowest total fish yield was obtained at control ponds. This data indicate that the 60-kg dose represents the most economical level for total fish production and its constituents.

Table 2 showed the chemical composition of whole fish body as a percentage of the dry matter. While, there were no significant variations in dry matter, crude protein, total lipids and ash contents were significantly different for different levels of fertilization. The high protein content was obtained at the 20-100 kg/acre/month doses with insignificant differences (57.56-59.26%), while the least protein content was obtained at control ponds (54.46%). Moreover, total lipids were slightly affected by the applied doses of 20, 40, 60 and 100 kg/acre/month (11.65, 12.04, 12.46 and 13.25%, respectively) except that of the control (13.02%). Ash contents were gradually increased with the doses of 20, 40 and 60 kg/acre/month (23.79, 25.48 and 27.97%, respectively), while the highest dose led to low ash content (24.67%). The ash content of control samples (29.08%) was superior to the treated ones.

Discussion

In this study, no significant difference in temperature was observed among the different ponds. This result is due to the warm climate and the shallowness of most tropical fish ponds (~1.0 m), so, temperature and light are not likely to be limiting (McNabb *et al.*, 1988). On the other hand, the lowering of Secchi disk visibility by pond fertilization is due to the high abundance of phytoplankton and/or the high turbidity, which may be resulted from colloidal clay particles (Boyd, 1990). Moreover, the concentration of dissolved oxygen was not affected in this study although phytoplankton biomass indicated by chlorophyll 'a' content increased ($r = 0.147$). This result may be due to the consumption of dissolved oxygen through organism's respiration, however, dissolved oxygen is a causing factor for fish growth ($r = 0.649$). Also, the microbial activity for oxidation of organic matter, which resulted from fish faeces and organisms death, is responsible for oxygen depletion.

High concentrations of orthophosphate were observed with the 60 and 100-kg doses with insignificant difference. This may be due to the increase of nutrients load through the increase of fertilizer dose although there are many pathways for phosphorus in aquatic ecosystem. On the other hand, phosphorus could be absorbed and accumulated by bacteria, phytoplankton and sediments (Boyd and Musig, 1981; Boyd, 1990; Munsiri *et al.*, 1995). Also, phosphate, in hard water could react quickly with calcium to form calcium phosphate, which would settle from the water within hours or days (Bennett and Adams, 1976; Masuda and Boyd, 1994). Boyd and Tucker (1998) reported that phosphorus requirements also are related to total alkalinity. On the other hand, there were no changes in nitrate levels due to fertilizer doses. This may be due to the fact that inorganic nitrogen added to fishponds was transformed through denitrification and/or converted to ammonia that volatilizes to the atmosphere (Gross *et al.*, 1999; 2000). Furthermore, nitrogen could be quickly absorbed and accumulated inside phytoplankton cells (Boyd, 1990). Furthermore, unionized (free) ammonia was low (<0.5 mg/L) to be toxic to Nile tilapia (Abdalla *et al.*, 1996).

It is well known that, the change in physico-chemical characteristics of water body leads to concomitant quantitative changes in phytoplankton organisms. In this study, phytoplankton biomass (represented by chlorophyll 'a' content) increased with increasing the fertilizer dose ($r = 0.65$) due to the increase in nutrients budget in ponds. This result means that where nutrients concentration increased, the managed ponds have denser phytoplankton population than unfertilized ponds, therefore, there was an obvious increase in chlorophyll 'a' content. Similar results were obtained by Diana *et al.* (1991) who found that fishponds that received higher doses of fertilizer exhibited higher primary productivity than that received low doses of fertilizer.

The stepwise regression, for phytoplankton abundance (indicated by chlorophyll 'a' content) in ponds received inorganic fertilizer, evoked that the best model is:

Chlorophyll 'a' content = 164.21 + 1.51 (PO_4)
+ 13.08 (NO_3) + 0.34 (F-dose)
– 1.55 (Fish growth)
– 2.69 (Temperature)

The model represents 60.8% of the total data where chlorophyll 'a' content was inversely proportional to fish growth and temperature, while it is directly proportional to phosphate level, nitrate level and fertilizer dose. Also, the model evoked that these relationships were highly significant and linearly fitted with tilapia growth ($r^2 = 0.608$; $P<0.001$).

The growth of Nile tilapia was increased with increasing the fertilizer dose and the 60-kg/acre/month dose is the optimum for an economically valuable production of Nile tilapia (adult and fry) especially that there is no significant difference between the data at the 60 and 100-kg/acre/month doses ($P>0.05$). These results are in agreement with Batterson *et al.* (1989) and Diana *et al.* (1991), who reported that the yield of cultured fish was increased by increasing the quantity of applied fertilizer. On the other hand, the slight difference between the results at the 60 and 100-kg/acre/month doses may be due to phytoplankton flourishing and blooming at the 100-kg dose, which interfered with fish production and became a limiting factor in fishponds causing problems with water quality.

The stepwise regression, for tilapia growth in ponds received inorganic fertilizer, evoked that the best model is:

Fish growth = 135.83 + 0.53 (PO_4)
+ 0.06 (F-doses) + 2.05 (DO) – 1.48 (Temperature)
– 0.12 (Chlorophyll 'a')
– 6.17 (pH) – 0.52 (Secchi disk)

The model represents 85.1% of the total data where fish growth was inversely proportional to temperature, phytoplankton abundance (indicated by chlorophyll 'a' content), pH values and Secchi disk reading. Otherwise, it is directly proportional to phosphate level, fertilizer dose and dissolved oxygen. This model evoked that these relationships were highly significant and linearly fitted with tilapia growth ($r^2 = 0.851$; $P<0.001$).

With regard to the proximate chemical composition of whole fish body, protein content was insignificantly differat the fertilizer levels, while the least protein content was obtained for fish in the control ponds. Total lipids were slightly affected at the fertilizer level. Ash contents were gradually increased with the 20, 40 and 60 kg doses. This is due to the accumulation of nutrients in fish tissues through fish grazing and accumulation of planktonic organisms (Boyd, 1990). Moreover, the increase in fertilizer dose stimulated phytoplankton productivity, so, the activity of fish grazing and accumulation of nutrients into fish may be increased by increasing the availability of organisms in ponds.

Conclusion

It could be concluded from this study that only Secchi disk reading, orthophosphate, total nitrogen concentrations and chlorophyll 'a' content were significantly affected by the application of fertilizer. The optimum dose of inorganic fertilizer (20:20:5 NPK) for production of Nile tilapia without artificial feeding is 60 kg/acre/month. Further work is needed to evaluate the combination of inorganic with organic fertilization and artificial feeding in monoculture and polyculture systems.

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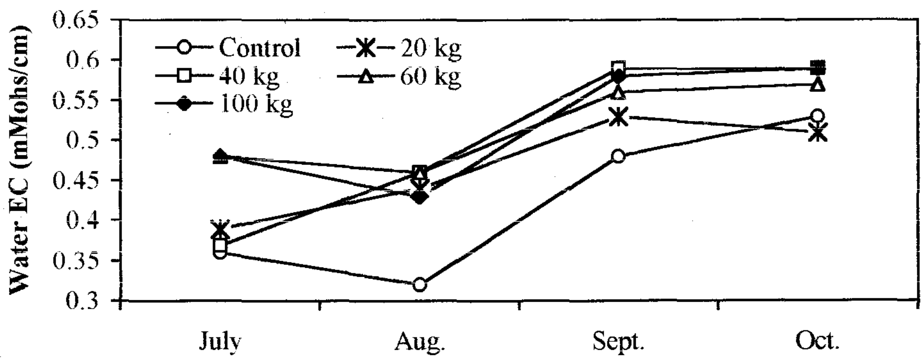
Table 1

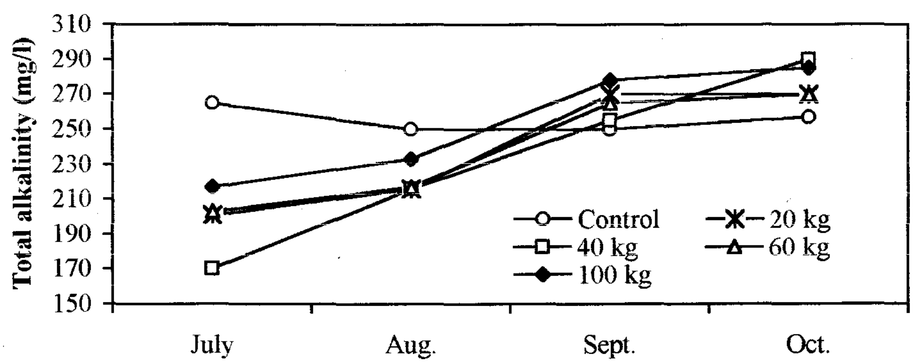
Changes in water physico-chemical parameters of earthen ponds that received different doses of inorganic fertilizer.

Parameters	Doses of inorganic fertilizer (kg/acre/month)					P*
	Control	20	40	60	100	
Temperature (°C)	25.5 a (21.8-28.2)	25.7 a (21.9-28.3)	25.6 a (22.0-28.1)	25.7 a (22.1-28.3)	25.6 a (22.0-28.1)	0.997
Secchi disk (cm)	20.7 a (19.5-21.5)	18.7 b (17.5-20.1)	18.1 b (16.7-19.5)	17.0 b (16.2-18.0)	17.1 b (15.5-18.5)	0.021
Dissolved oxygen (mg/L)	4.64 a (3.13-5.77)	5.34 a (4.10-6.63)	5.05 a (3.63-6.33)	5.06 a (3.94-6.45)	5.089 (3.58-6.95)	
The pH value	8.1 a (7.9-8.3)	8.2 a (7.9-8.7)	8.1 a (7.8-8.6)	8.2 a (7.9-8.5)	8.2 a (8.0-8.5)	0.970
Free ammonia (mg/L)	0.07 a (0.4-0.11)	0.09 a (0.06-0.13)	0.09 a (0.05-0.12)	0.10 a (0.06-0.18)	0.11 a (0.06-0.14)	0.513
Conductivity mMohs/cm	0.42 a (0.26-0.57)	0.47 a (0.36-0.57)	0.50 a (0.33-0.67)	0.52 a (0.43-0.61)	0.52 a (0.39-0.64)	0.521
Total alkalinity (mg/L)	256 a (220-265)	239 a (201-270)	233 a (170-290)	239 a (203-270)	253 a (217-285)	0.900
Total hardness (mg/L)	179 a (154-198)	175 a (155-195)	179 a (151-206)	192 a (174-216)	192 a (167-221)	0.730
Orthophosphate (µg/L)	0.361 b (0.32-0.40)	0.571 b (0.39-0.69)	0.753 ab (0.45-1.014)	1.306 a (0.80-1.614)	1.363 a (1.0-2.049)	0.004
Nitrate (mg/L)	10.91 a (7.38-13.45)	13.43 a (9.93-19.66)	13.71 a (9.45-17.85)	17.62 a (10.7-24.57)	16.03 a (10.5-18.47)	0.305
Total nitrogen (mg/L)	6.41 b (5.50-6.93)	7.14 ab (6.58-7.96)	7.24 ab (6.77-7.70)	7.42 ab (7.38-8.73)	8.55 a (7.38-10.53)	0.042
Chlorophyll a (µg/L)	47.51 c (37.5-58.3)	51.63 c (39.3-77.9)	63.5 bc (47.1-93.43)	76.32 b (62.2-95.8)	91.95 a (87.3-99.1)	0.019

* P = Probability.

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





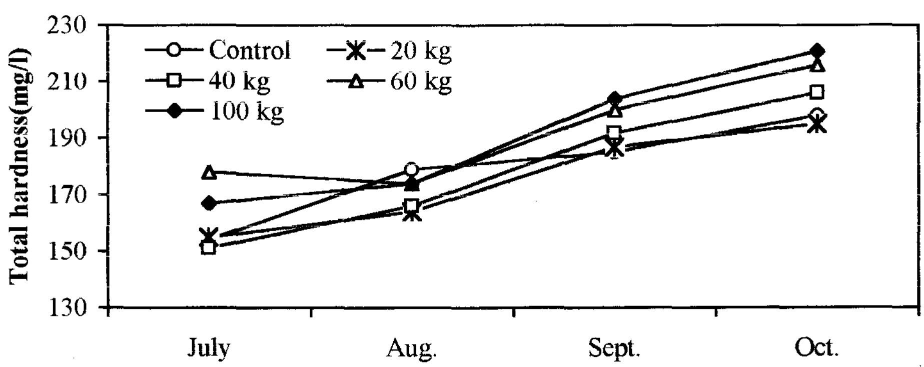


Fig 1. Monthly variations of water conductivity (mMohs/cm), total alkalinity and total hardness (mg/L $CaCO_3$) in ponds water affected by different doses of inorganic fertilizer.

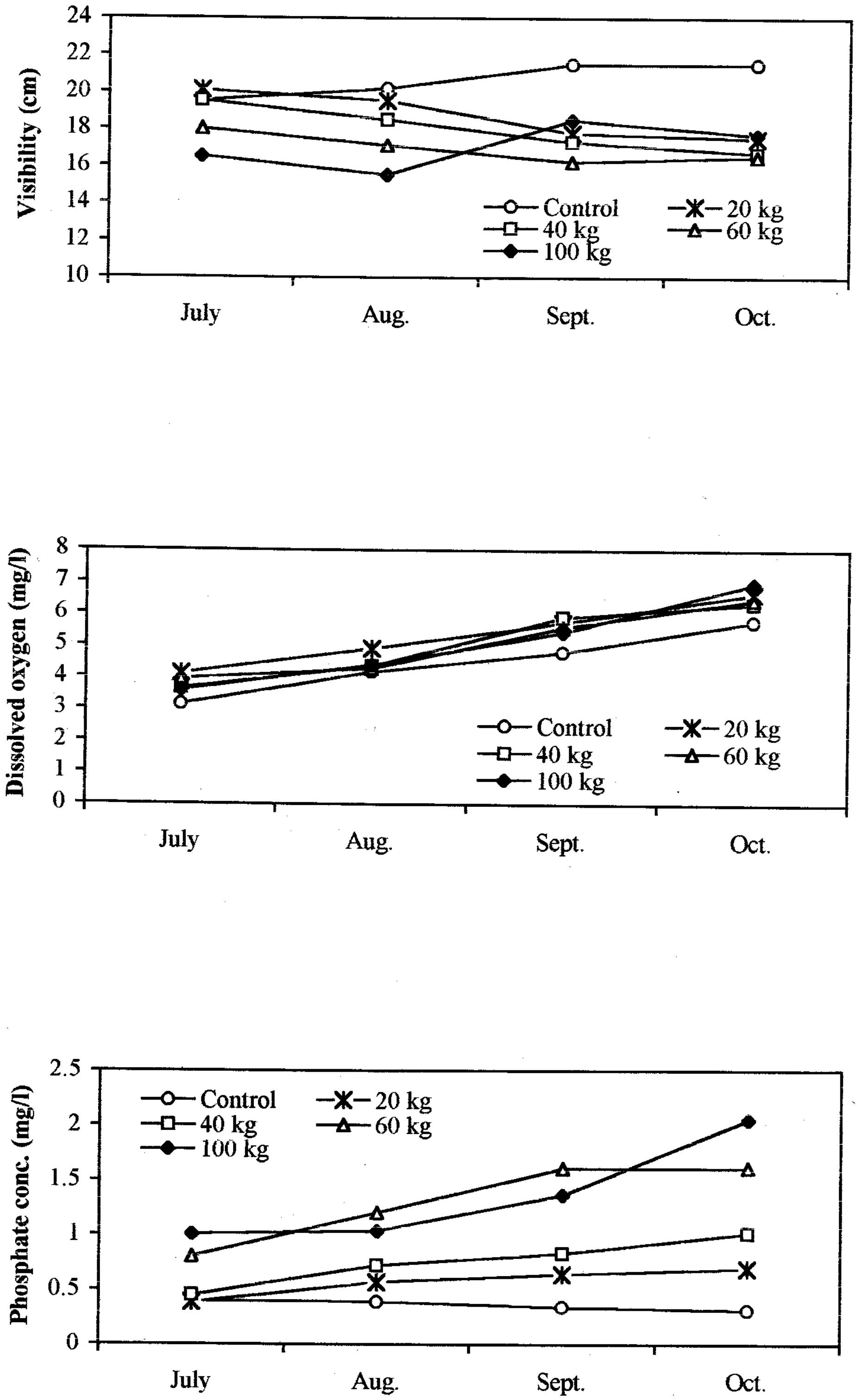


Fig 2. Monthly variations of visibility (cm), dissolved oxygen (mg/L) and phosphate concentration (mg/L) in ponds water affected by different doses of inorganic fertilizer.

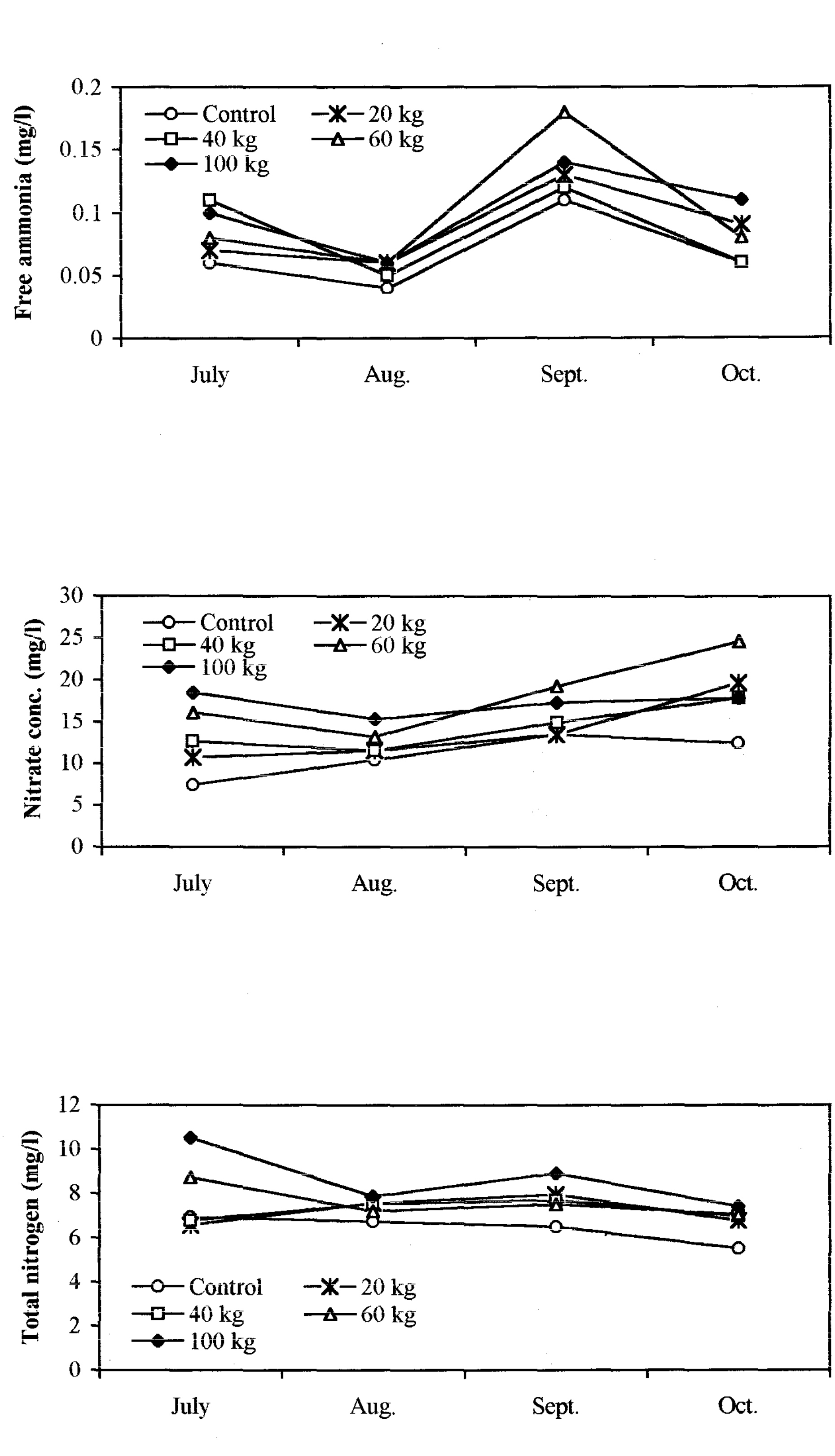


Fig 3. Monthly variations of free ammonia, nitrate and total nitrogen concentration (mg/L) in ponds water affected by different doses of inorganic fertilizer.

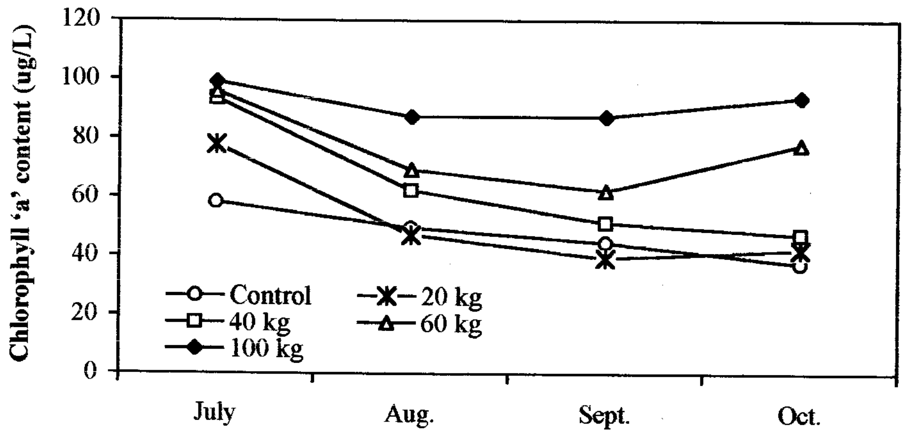


Fig 4. Monthly variation of chlorophyll a content (g/L) in ponds water that received different doses of inorganic fertilizer.

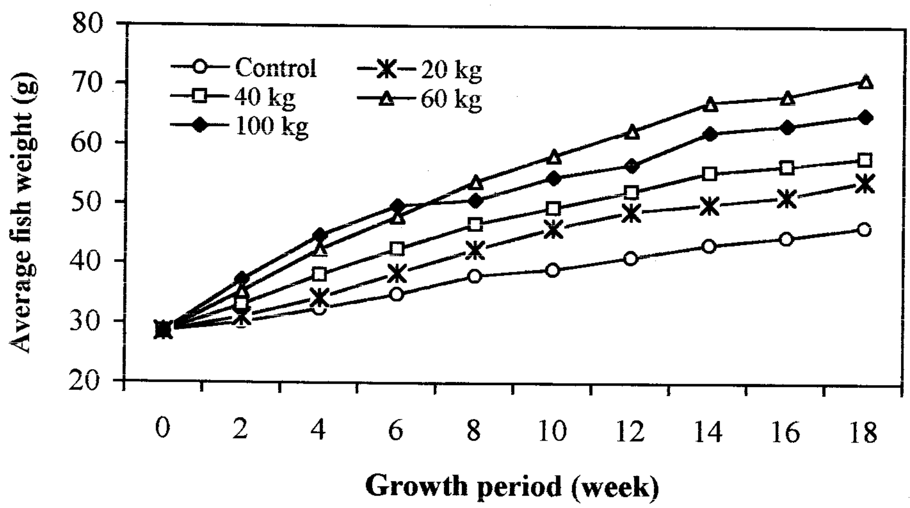


Fig 5. Fish growth of Nile tilapia with different doses of inorganic fertilizer.

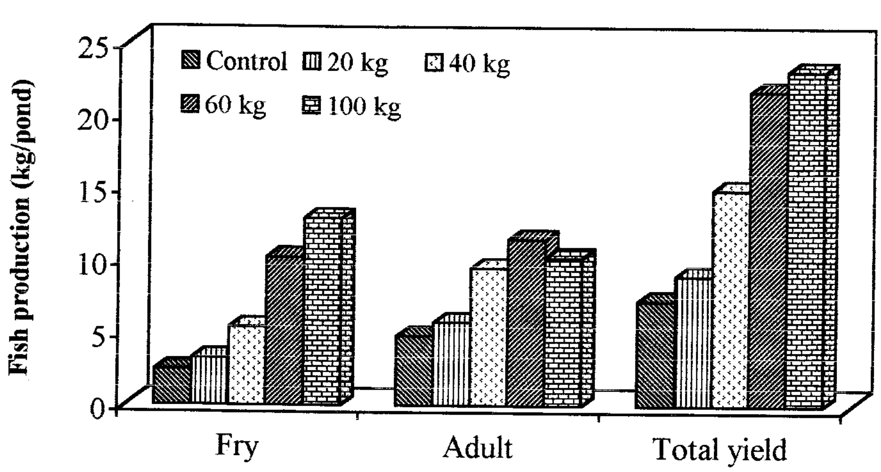


Fig 6. The total production of Nile tilapia (kg/pond) in ponds that received different doses of inorganic fertilizer.

Table 2

Carcass proximate chemical analyses of Nile tilapia (*O. niloticus*) reared in ponds that received different doses of inorganic fertilizer.

Fertilizer doses	Dry matter	Crude protein	Total lipids	Ash
Control	23.6 a ± 0.39	54.46 b ± 0.80	13.02 a ± 0.04	29.18 a ± 0.33
20 kg	23.6 a ± 0.13	57.56 a ± 0.33	11.65 b ± 0.02	23.79 c ± 0.29
40 kg	24.8 a ± 0.13	58.03 a ± 0.42	12.04 b ± 0.05	25.48 b ± 0.02
60 kg	24.3 a ± 0.13	58.5 a ± 0.18	12.46 b ± 0.12	27.97 a ± 0.10
100 kg	24.7 a ± 0.17	59.26 a ± 0.33	13.25 a ± 0.01	24.67 bc ± 0.25

Means in the same column not having the same letters are significantly different ($P<0.05$).