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Article

Assessment of Fertilizer Application Intervals for Giant Gourami (*Osphronemus goramy* Lacepede) in Ponds

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Abstract

The experiment was conducted in twelve 400 m^2 earthen ponds at Walailak University, Thailand, to investigate the effects of fertilizer application intervals on production performances of giant gourami and pond water quality. Fertilizer applications at 1, 2, 3 and 4-week intervals were replicated three times in a completely randomized design. Ammonium phosphate and ammonium sulfate were used at application rates of 9 kg N plus 4.5 kg P_2O_5 ha^{-1} ($N:P_2O_5 = 2:1$) as a source of nitrogen and phosphorus. Fish of an average weight of 2.2 ± 0.1 g were stocked at 1 fish/m^2. After the 120 day trial was finished, the results showed that the survival rate was not significantly different ($p > 0.05$) but final weights, growth rates and net productions were significantly different ($p < 0.05$). Fertilizer applications at 4-week intervals showed the highest (average ± SD) final weights, growth rates and net productions which were 37.6 ± 3.4 g, 0.3 ± 0.03 gd^{-1} and 330 ± 2.5 kg/ha respectively. However, most water quality parameters were not significantly different ($p > 0.05$) and were in the range for optimal growth of fish. In addition, the result from regression analysis showed that fertilizer application intervals gave a high positive correlation with fish productions ($r = 0.76$, $p < 0.01$). In conclusion, the results suggest that fertilizer applications at 4-week intervals could have practical use in the giant gourami ponds to produce fish ranging from 2.2 ± 0.1 - 37.6 ± 3.4 g size during the 120 day production.

Keywords: Phosphorus, fertilizer, freshwater fish ponds, water quality, giant gourami, *Osphronemus goramy* Lacepede

Introduction

Giant gourami *Osphronemus goramy* is a herbivorous, freshwater fish belonging to the family Osphronemidae (**Figure 1**). This species is native to parts of Indochina, Malaysia, Indonesia, and India where it contributes to capture fisheries, and it was introduced into other Asian countries to control aquatic vegetation [1]. In Thailand and some other Southeast Asian countries, there are programs promoting giant gourami for aquaculture.

Giant gourami is considered a valuable food fish species in Thailand with aquaculture potential and wide consumer acceptance. Market prices tend to be stable year round and higher than those of common, freshwater fish. Giant gourami is grown primarily at farms in the central plain in Suphanburi, Nakhonsawan, Uthaithani, and Ayutthaya Provinces. The total production of gourami in 2002 was about 5,452 mt divided among culture methods as follows: pond, 60.17 %; cage, 31.76 %; ditch, 8.03 % [2].

Figure 1 A giant gourami *Osphronemus goramy* from the trial.

Many small-scale Asian aquaculture producers use fertilizers to increase giant gourami production because of the high price of feed. There have not been studies of fertilization of gourami ponds such as have been conducted for many other fish species [3]. Production levels are similar for giant gourami and sunfish (*Lepomis* spp.) cultured in ponds without feeding; thus, results of sunfish pond fertilization studies at Auburn University seem most applicable to giant gourami culture. The most recent recommendation for fertilization rates for sunfish ponds in the southeastern United States is 6 kg N and 3 kg P_2O_5 ha^{-1} per application at 4-week (wk) intervals was as effective in promoting sunfish production as fertilization at shorter intervals and the maximum production of bluegills *Lepomis macrochirus* was achieved at 6 kg N ha^{-1} at 3-wk intervals, treated by liquid fertilizers or pre-dissolved granular fertilizers in new ponds and in ponds from which sediment had recently been removed; nitrogen fertilization often may be reduced or omitted entirely in sunfish ponds fertilized for 5 years or more [4-6].

The present study was designed to ascertain whether or not the fertilization application interval recommended for sunfish ponds and bluegill ponds in the southeastern United States could be adjusted for use in giant gourami ponds.

Materials and methods

This experiment was conducted in twelve, 400 m^2 earthen ponds, each approximately 1 m in average depth, located at the Walailak University Aquatic Animal Scientific Laboratory Center (AASLC) about 15 km west of Thasala, Nakhon Si Thammarat, Thailand (8° 38′ 1″ N, 99° 51′ 45″ E). Mean, annual temperature is 26.5 °C (mean minimum = 24.0 °C, mean maximum = 29.1 °C). Ponds were constructed in 2008 on gray-colored, low organic-matter-content soil of the Thasala alluvial plain [7]. The water source is a reservoir filled by runoff from a rubber tree plantation. This water has total alkalinity and total hardness concentrations below 10 mg/l as $CaCO_3$ and is low in nutrient and organic matter concentrations.

Ponds were filled with water during May 2009 and treated with agricultural limestone at 2,000 kg/ha before stocking. Giant gourami (2.1 - 2.2 g/fish) were purchased from a commercial hatchery farm, Nakhonchaisri district, Nakhon Pathom, and 400 gourami fingerlings were placed in each pond on 20th May 2009. Water was added periodically during the study to replace evaporation and seepage, but levels were maintained about 10 cm below the elevation of discharge structures to avoid overflow after rain.

Four fertilizer application treatments, 1, 2, 3 and 4-wk intervals, were replicated three times in a completely randomized design. These four fertilizer intervals will be referred to as shorter (1-wk and 2-wk intervals), medium (3-wk intervals), and longer (4-wk intervals) fertilizer application treatments, respectively. The medium treatment applied the fertilizer at intervals equal to those recommended for sunfish ponds in the southeastern United States [5], and longer treatment provided the fertilizer at intervals equal to those recommended for bluegill ponds in the southeastern United States [6]. Ammonium phosphate (16 % N and 20 % P_2O_5) and ammonium sulfate (21 % N) were used as a source of nitrogen and phosphorus. Application rates were 2.25 kg N plus 1.13 kg P_2O_5 ha^{-1} weekly, 4.5 kg N plus 2.25 kg P_2O_5 ha^{-1} every 2 wk, 6.75 kg N plus 3.38 kg P_2O_5 ha^{-1} every 3 wk, or 9 kg N plus 4.5 kg P_2O_5 ha^{-1} every 4 wk. Hence, all ponds received the same quantity of fertilizer during the study. The treatment provided N and P_2O_5 (N:P_2O_5 = 2:1) inputs equal to those recommended for blue gill ponds in the southern USA. [62]. Fish of average weight 2.2 ± 0.1 g were stocked at 1 fish/m^2. Fertilizer for each pond was weighed and transferred to 20 L of pond water in a plastic bucket, the water and fertilizer were stirred thoroughly, and the slurry was splashed over the pond surface.

Water temperature, dissolved oxygen concentration, and pH were measured *in situ* with a polarographic dissolved oxygen meter and portable pH meter at 2 - 5 day intervals between 06.00 and 08.00 h and occasionally between 13.30 and 15.00 h. Water samples were taken midway between fertilizer application dates with a 90-cm water column sampler [8]. Samples were transported immediately to the laboratory and analyzed as described by [9] for chlorophyll-a (membrane filtration, acetone extraction, and spectroscopy), total alkalinity (acidimetry), and total hardness (EDTA titration). Aliquots of samples were also digested in alkaline persulfate solution, and the resulting nitrate and phosphate measured by the NAS reagent method [10] and the ascorbic acid procedure [9], respectively.

Ponds were drained and fish were harvested by seine and dip net 120 day after stocking on 28th August 2009. Total harvest weights and numbers of fish were obtained for each pond. A random sample of 30 fish was taken from each pond for length and weight measurements.

Data of initial weight, survival rate, final weight, growth rate, and net production among the fertilizer application interval treatments were subjected to one-way analysis of variance (ANOVA). Water quality data were tested by ANOVA. Differences among treatments were determined using DMRT at P = 0.05. Relationships between fish production and water quality were assessed by regression analysis using P = 0.05 to establish correlations between variables. Statistical analyses were made with the program Function R [11].

Results and discussion

The results of survival average 78.7 - 83.4 %, but did not differ among treatments. At the end of study, average weight of fish ranged from 25.9 g for the 1-wk interval treatment to 37.6 g for the 4-wk interval treatment. The average weight of the individual fish was not significant ($p > 0.05$) among 1, 2 and 3-wk interval treatments; fish were heaviest in the 4-wk interval treatment and differed ($p < 0.05$) from other treatments (**Table 1**). Net production and average daily growth rates also were not significantly different ($p > 0.05$) among 1, 2 and 3-wk interval treatments; net production and growth rate was highest for the 4-wk interval treatment and differed ($p < 0.05$) from other treatments.

It is difficult to predict the exact fertilizer interval for maximum production of giant gourami, since only 4 fertilizer intervals were applied due to the availability of ponds. However, the fact that the longer fertilizer intervals gave higher fish production than the medium and shorter fertilizer intervals and numerically greater (significantly greater) fish production than medium and shorter fertilizer intervals, suggesting that the longer fertilizer interval is an acceptable fertilizer interval. This evidence is similar to [6] suggesting that fertilization at 4-wk intervals was as effective in promoting sunfish production as fertilization at shorter intervals but differed from the suggestions of Wudthisin and Boyd [4]; Boyd and co-workers [5] reported that the maximum production of bluegills *Lepomis macrochirus* was achieved at 6 kg N ha^{-1} at 3-wk intervals, treated by liquid fertilizers or pre-dissolved granular fertilizers in new ponds and in ponds from which sediment had recently been removed.

Table 1 Average initial weight, final weight, growth rate, net production and survival rate of giant gourami in ponds treated at different intervals with 9 kg N plus 4.5 kg P_2O_5 ha^{-1} per application.

Variables	Application Interval			
	1-wk	2-wk	3-wk	4-wk
Initial Weight (g/fish)	2.2 ± 0.1^a	2.2 ± 0.1^a	2.1 ± 0.1^a	2.1 ± 0.2^a
Final Weight (g/fish)	25.9 ± 4.0^a	26.7 ± 2.3^a	26.0 ± 3.4^a	37.6 ± 3.4^b
Growth Rate (g/day)	0.2 ± 0.03^a	0.2 ± 0.02^a	0.2 ± 0.03^a	0.3 ± 0.03^b
Net Production (kg/ha)	186.8 ± 6.2^a	196.2 ± 3.6^a	196.8 ± 3.8^a	330.6 ± 2.5^b
Survival Rate (%)	78.7 ± 2.8^a	80.0 ± 2.0^a	82.6 ± 1.6^a	83.4 ± 4.3^a

[1]Value are means ± SD of triplicate replications. Mean ± SD within the same row with the same superscript are not significantly different at P = 0.05 determined by the Duncan's new multiple-range test.
[2]Fertilizer treatments application interval (1-wk, 2-wk, 3-wk and 4-wk) from May 20, 2009 to August 28, 2009.

Water quality variables fluctuated greatly among treatments, ponds, and dates as typically observed in pond fertilization studies [8]. Thus, only treatment grand means were reported (**Table 2**).

The lowest and highest measured water temperatures in individual ponds were 27.7 °C and 28.8 °C. Means for water temperature did not differ among treatments and ranged from 28.1 to 28.5 °C. Water temperature was within an acceptable range for culture of giant gourami [1], and the fertilizer interval was not correlated with water temperature.

The pH of surface waters in individual ponds varied from 7.1 - 7.7 as a result of differences in phytoplankton photosynthesis rate. The mean pH did not differ and range from 7.2 - 7.5. Fertilized ponds typically have high pH in surface water, but this phenomenon does not prevent a positive response of fish production to fertilization [3]. Fertilizer intervals were not correlated with pH.

The lowest, morning dissolved oxygen concentrations measured in a single pond was 5.5 mg/l; no other pond had a value below 5 mg/l. Afternoon concentrations of dissolved oxygen in surface water normally were above saturation. Means for dissolved oxygen concentrations measured between 06.00 and 08.00 h ranged between 5.7 and 6.1 mg/l and did not differ. Fertilizer intervals were not correlated with dissolved oxygen concentration.

Total alkalinity concentration in individual ponds varied from 13.9 - 44.0 mg/l, but treatment means of 17.8 - 31.9 mg/l did not differ (**Table 2**). Total hardness concentration exhibited variability similar to that of total alkalinity concentration, and treatment means (33.8 - 54.4 mg/l) did not differ (**Table 2**). Total hardness concentration was consistently higher than the total alkalinity concentration by 5 - 20 mg/l. This is a typical result of liming acidic ponds, because bicarbonate from dissolution of liming material, the source of alkalinity, is expended in neutralizing acidity; the calcium and magnesium ions from the liming material, the source of hardness, remain in solution [3]. Both alkalinity and hardness averaged above the minimum concentration of 20 mg/l considered acceptable for fertilized ponds with fish standing crops of 1,000 kg/ha or less [3]. Fertilizer intervals were not correlated with total alkalinity and total hardness concentration (**Figure 2**). Total hardness tended to increase with longer fertilizer interval and to promote fish production at greater hardness.

Table 2 Water quality variables[1] in giant gourami ponds treated with ammonium phosphate and ammonium sulfate at 1, 2, 3 and 4 week intervals.

Variables	Application Interval			
	1-wk	**2-wk**	**3-wk**	**4-wk**
pH	7.2 ± 0.11[a]	7.5 ± 0.15[a]	7.5 ± 0.23[a]	7.4 ± 0.19[a]
Temperature (°C)	28.5 ± 1.10[a]	28.3 ± 0.75[a]	28.1 ± 3.22[a]	28.2 ± 0.97[a]
Dissolved oxygen (mg/l)	6.1 ± 0.2[a]	5.9 ± 0.05[a]	5.7 ± 0.6[a]	5.8 ± 0.3[a]
Total alkalinity (mg/l)	17.8 ± 3.8[a]	31.9 ± 9.9[a]	28.0 ± 15.1[a]	26.4 ± 5.8[a]
Total hardness (mg/l)	33.8 ± 5.8[a]	54.38 ± 15.96[a]	54.38 ± 19.47[a]	48.4 ± 12.25[a]
Total nitrogen (mg/l)	0.120 ± 0.061[a]	0.137 ± 0.040[a]	0.116 ± 0.011[a]	0.128 ± 0.056[a]
Total phosphorus (mg/l)	0.017 ± 0.005[a]	0.014 ± 0.004[a]	0.058 ± 0.046[a]	0.022 ± 0.004[a]
Chlorophyll _a_ (mg/l)	248.4 ± 65.5[a]	436 ± 297.6[a]	301.9 ± 144.7[a]	218.0 ± 81.18[a]

[1]Mean ± SD within the same row with the same superscript are not significantly different at P = 0.05 based on the Duncan's new multiple-range test.

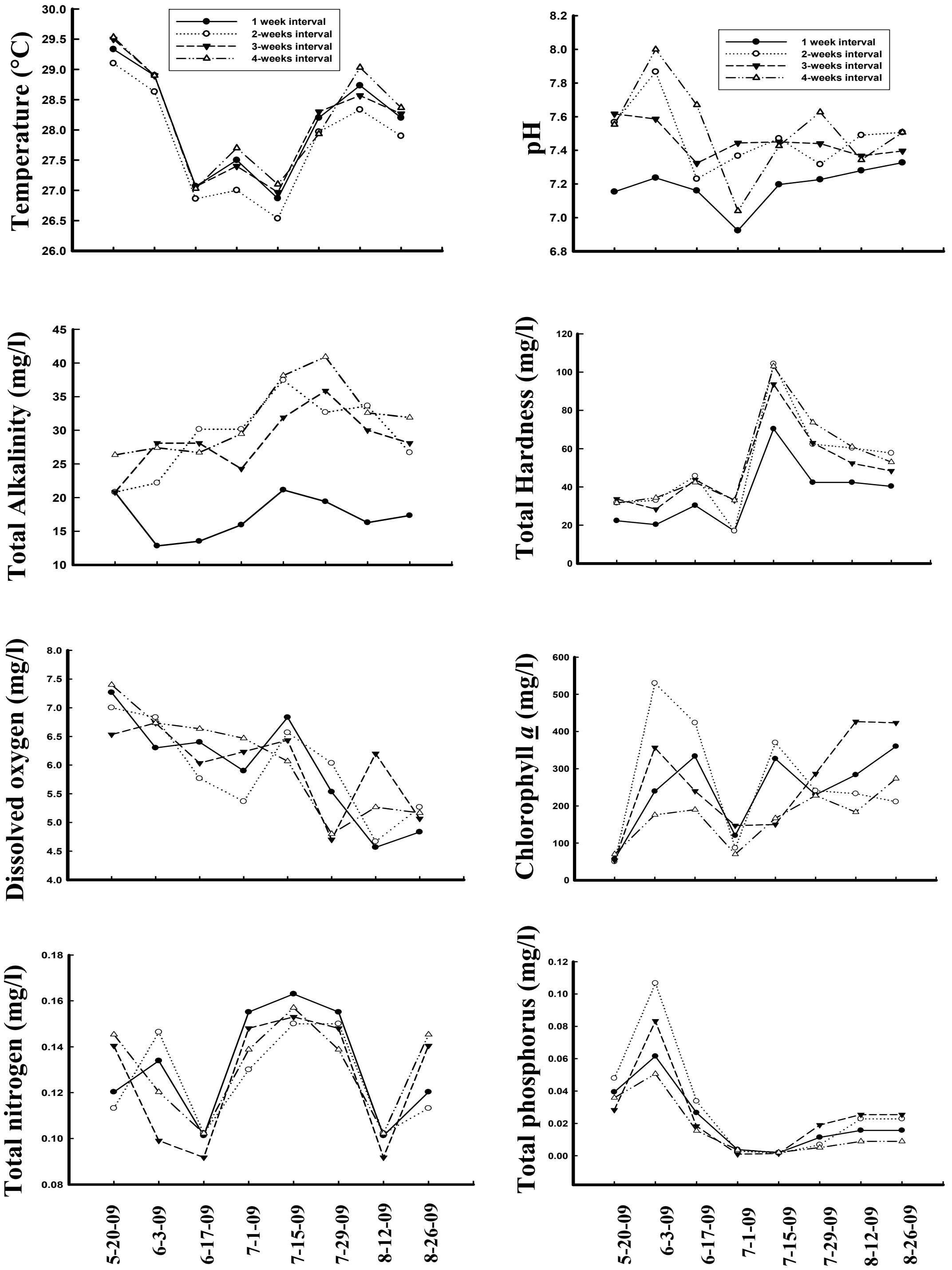

Figure 2 Average concentrations of water variables from 20th May 2009 to 26th August 2009 in water of giant gourami ponds treated with ammonium phosphate and ammonium sulfate at 1, 2, 3 and 4 week intervals.

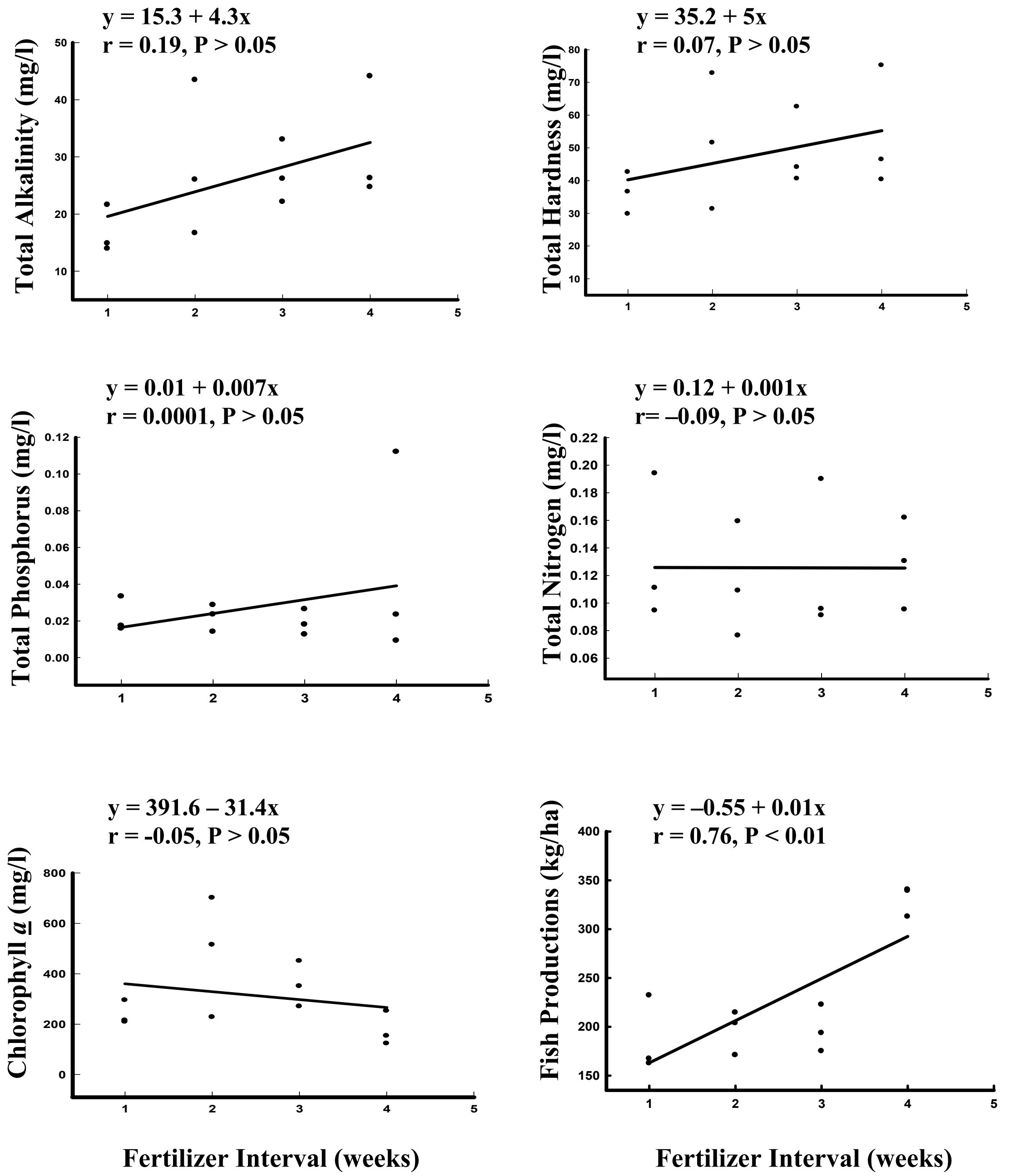

Figure 3 Relationship between fertilizer interval and water quality variables and fish productions in giant gourami ponds. Ammonium phosphate and ammonium sulfate were nutrient sources, at 1, 2, 3 and 4 week intervals.

Treatment means for total nitrogen and total phosphorus concentrations did not differ (**Table 2**) in spite of the difference in amounts of these 2 nutrients applied in fertilizer. There was no correlation between these nutrient concentrations and fertilizer intervals. Fertilizers almost completely dissolve when pre-mixed with water and splashed over pond surfaces [3] as done in this study. However, nitrogen and phosphorus are absorbed quickly by phytoplankton or assimilated by other processes within pond ecosystems. About two-thirds of phosphorus applied to ponds in feeds and fertilizers is sequestered by sediment [12]. Nitrogen applied in ammonia may be lost to the atmosphere by diffusion - especially when the pH is above 8 [10]. Ammonia also is oxidized to nitrate by nitrifying bacteria, and nitrate, in turn, is denitrified by denitrifying bacteria to nitrogenous gases that diffuse into the air. Of course, some nitrogen accumulates in the sediment as a component of organic matter. Concentrations of nitrogen and phosphorus obviously increased following fertilization, but water samples were collected midway between fertilization dates. At the time of sampling, natural processes had already reduced concentrations of nutrients in pond water.

Fish production was correlated with fertilizer interval; the relationship was a positive correlation ($r = 0.76$; $p < 0.01$), and fish production tended to increase at longer fertilizer intervals (**Figure 3**). Ponds with the shorter and the greatest fertilizer inputs no doubt had high ammonia concentration immediately following applications of ammonium phosphate and ammonium sulfate, and this may have stressed the fish; adverse effects on fish reproduction was observed in sunfish ponds treated with more than 8 kg N ha^{-1} from ammonium nitrate [5].

The mean chlorophyll a concentration, a measure of phytoplankton abundance, was higher in shorter fertilizer interval treatments than in the other treatments (**Table 2**). Mean chlorophyll a concentrations ranged from 218 - 436 mg/l and did not differ among treatments. However, concentrations tended to be numerically greater in the medium and the shorter fertilizer interval treatments than in the longer fertilizer interval treatments. Nevertheless, chlorophyll a concentration was correlated with concentrations of both total nitrogen and total phosphorus. Fish production was positively correlated with chlorophyll a concentration [1].

Chlorophyll a concentration tended to decline at total hardness concentration above about 50 mg/l. This likely resulted from precipitation of phosphorus from water as calcium phosphate at greater calcium concentration. The relationship also explains why fish production tended to decline at high total hardness concentrations.

Conclusions

This study suggests that the optimum fertilizer interval applications for giant gourami in southern Thailand ponds should usually be made at 4-wk intervals with ammonium phosphate (16 % N and 20 % P_2O_5) and ammonium sulfate (21 % N) 9 kg N plus 4.5 kg P_2O_5 ha^{-1} ($N:P_2O_5 = 2:1$) as a source of nitrogen and phosphorus. However, if a pond has a heavy phytoplankton bloom on the scheduled day, fertilization should be delayed. Moreover, in old ponds fertilized for 5 years or more and sediment ponds were removed; nitrogen fertilization often may be reduced or omitted.

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