EFFECTS OF FERTILIZATION AND FEEDING STRATEGY ON WATER QUALITY, GROWTH PERFOMANCE, NUTRIENT UTILIZATION AND ECONOMIC RETURN IN NILE TILAPIA (*Oreochromis niloticus*) PONDS

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Abstract

The present research was conducted in six 280-m^2 earthen ponds at Bang Sai, Thailand, to investigate and compare water quality, growth performance, nutrient utilization, and economic return for Nile tilapia culture with two fertilization and feeding strategies. There were two treatments in triplicate each: (A) fertilizing ponds throughout the culture period and feeding Nile tilapia starting from day 80; (B) fertilizing ponds until day 80 and feeding Nile tilapia starting from day 80. Ponds were stocked with sex-reversed all-male Nile tilapia at 3 fish m^{-2}.

The study showed that tilapia growth in treatment A was significantly better than that in treatment B. Final mean weight of tilapia in treatment A was 312±1.8 g and mean daily weight gain was 1.8±0.0 g day^{-1}, whereas in treatments B final mean weight was 248±17.5 g and mean daily weight gain was 1.4±0.2 g day^{-1}. Net tilapia yield in treatments A and B was 16.7±0.4 and 13.0±1.4 t $ha^{-1}year^{-1}$, respectively. Overall mean concentrations of total alkalinity and total ammonia nitrogen were significantly higher in treatment A than those in treatment B, however, the overall mean values of all other measured water quality parameters were not significantly different between the two treatments. Total inputs of nitrogen and phosphorus through fertilizer and feed over the culture period were significantly higher in treatment A than those in treatment B, however, percentage recovery of N and P in the harvested biomass was higher in treatment B than that in treatment A. Economic analysis showed that tilapia culture practice with fertilization plus feeding (treatment A) generated 50% additional gross revenue as compared to the fertilization followed by feeding (treatment B). Moreover, treatment A showed a positive return, whereas a negative return was observed in treatment B. Apparently, better economic return in treatment A is due to the improved growth performance of Nile tilapia in treatment A than in treatment B, which might have been influenced by the presence of plenty of natural food in the ponds. The results suggest

therefore that combination of fertilization and feeding should be a preferred strategy over fertilization followed by feeding for culturing Nile tilapia.

Introduction

Tilapia is one of the most important species for the 21st century aquaculture and is produced in more than 100 countries (Fitzsimmons, 2000). Nile tilapia *Oreochromis niloticus* is cultured worldwide mostly in semi-intensive culture systems using fertilization. Nevertheless, variety of pond input schemes, including inorganic and/or organic fertilizers, formulated feed and combination of both, were involved in Nile tilapia production. Previous researches have shown that supplemental feeding in fertilized ponds resulted in significantly higher growth rates and greater yield than fertilization alone (Green, 1992; Diana *et al*., 1994a). Diana *et al*. (1996) emphasized that from a pond management perspective, fertilization early in the grow-out, then adding supplemental feed once Nile tilapia reach 100-150 g, is the efficient way to grow large tilapia. However, excessive increase in variable cost due to the high price of formulated feed is a growing concern among tilapia growers as this could lead to a negative net return and thus, an economically unviable practice. Certainly, it is the economic viability of aquaculture practice, more than any other factor, which influences its long-term adoptability and, therefore, proper assessment of economic performance of culture system is essential.

Another important issue is the nutrient utilization efficiency of the culture system as only a small proportion of the total nutrient inputs are being assimilated in the harvested biomass and major portion is being lost to the system. Edwards (1992) mentioned that in a culture system with high fertilization rates, the nutrients assimilated in fish biomass was estimated to be less than 20% for nitrogen (N) and 10% for phosphorus (P). Eventually, the small proportion of the total nutrient inputs being retained in the harvested biomass makes the system nutrient inefficient and fate of the waste generated raises serious environmental concern. As aquaculture wastewater outputs and load vary widely depending upon the species and farming system, and aquatic environment employed (Boyd and Queiroz, 2001), information on nutrient utilization is essential to estimate the efficiency of nutrient retention by culture species and release to the environment (Bergheim and Asgard, 1996). Therefore, on the one hand, feeding strategy must be developed to minimize feed wastage and deterioration of water quality. On the other hand, it should be sufficiently profitable to make the operation economically viable. Keeping these in view, an attempt has been made to investigate and compare water quality, growth performance, nutrient utilization and economic return in a tilapia grow-out system with different fertilization and feeding schemes.

Materials and methods

The experiment was conducted in six 280-m^2 earthen ponds at the Ayutthaya Freshwater Fisheries Station located at Bang Sai (14°45’ N, 100°32’E), approximately 60 km northwest of Bangkok, Thailand. There were two treatments in triplicate each: (A) fertilizing ponds throughout the cultural period and feeding Nile tilapia starting from day 80;

(B) fertilizing ponds until day 80 and feeding Nile tilapia starting from day 80. Sex-reversed all-male Nile tilapia with an average weight of 23-24 g were stocked at 3 fish/m^2 (840 per pond). All ponds were fertilized weekly with urea and triple super phosphate (TSP) at rates of 28 kg N and 7 kg P/ha/week to make N:P ratio to 4:1. Nile tilapia in both treatments were fed commercial floating pelleted feed (30% crude protein, Charoen Pokphand Co., Ltd., Thailand) starting from day 80 of the culture period. Satiation feeding rate was determined for each pond by estimating the total amount of pelleted feed consumed during one hour in the morning (1000-1100 h) and one hour in the afternoon (1400-1500 h) on the first day of each week. The 50% of mean satiation feeding rate for each treatment was used for all the three ponds in the treatment over the reminder of the week. Pond water level was maintained at 1 m by topping up weekly to replace losses due to seepage and evaporation.

Mean fish weight was determined at initial and final harvest, as well as 40 fish from each pond was sampled randomly and batch weight was taken to assess fish growth biweekly. Fish were harvested after 160 days of culture. Column water samples were taken biweekly for analyses of pH, alkalinity, total ammonia nitrogen (TAN), nitrite-nitrogen (NO_2-N), total Kjeldahl nitrogen (TKN), soluble reactive phosphate (SRP), total phosphorus (TP), and chlorophyll *a* using standard methods (APHA *et al*., 1985; Egna *et al*., 1987). Dissolved oxygen (DO) and temperature were also measured *in situ* at 20 cm below the water surface before taking water samples using a YSI model 54 oxygen meter (Yellow Springs Instruments, Yellow Springs, OH). Nutrient inputs for N and P in ponds during the experimental period were calculated based on inputs from fertilizer and pelleted feed, and gain in the harvested fish.

Economic analysis was conducted to determine economic returns of the two treatments tested during the experiments (Shang, 1990). The analysis was based on farm-gate prices in Thailand for harvested fish and current local market prices for all other items expressed in US dollar (US$1 = 40 baht). Farm-gate price of Nile tilapia varied with size: $0.375 kg^{-1} for size 100-200 g, $0.50 kg^{-1} for size 200-299 g, $0.60 kg^{-1} for size 300-500 g, and $0.80 kg^{-1} for size more than 500 g. Market prices for fingerlings of sex-reversed Nile tilapia ($0.009 $piece^{-1}$), urea ($0.170 kg^{-1}), TSP ($0.30 kg^{-1}) and feed ($0.50 kg^{-1}) were applied in the analysis. The calculation for cost of working capital was based on an annual interest rate of 8%. Economic performance of the two feeding strategies were compared in terms of total variable cost (including cost of urea, TSP, feed, and cost of working capital), gross revenue (from selling tilapia), and net return (gross revenue-total variable cost).

Data were analyzed by one way analysis of variance to sort out the effects of treatment on water quality, fish growth, production, nutrient inputs and gains, and economic returns. Differences were considered significant at an alpha level of 0.05. All means were given with ± standard error (SE).

Results

Fish growth performance in treatment A was significantly better than that in treatment B ($P < 0.05$; Table 1). Final mean weight was 314±1.8 g $fish^{-1}$ with a total yield of 227.8±4.4

kg pond^{-1} in treatment A, compared to mean weight of 248±17.5 g fish^{-1} and total yield of 182.4±16.9 kg pond^{-1} in treatment B. Mean weight in both treatments remained almost same till the first 80 day of the experiment, but a higher mean weight was observed in treatment A than that in treatment B in the later half of the study (Fig. 1). Daily weight gain in both treatments was similar up to day 80 (Fig. 2), but was significantly higher in treatment A than that in treatment B for the second 80 days of culture as well as for overall mean of the entire culture cycle (Table 1). Growth rate in treatment A was 2.66 g d^{-1} and in treatment B, 1.96 g d^{-1} for the second 80 days of culture. Mean survival rate was similar (87%) in both the treatments. Mean net fish yield was significantly higher in treatment A than that in treatment B ($P > 0.05$), ranging from 17.2 to 10.4 t ha^{-1} y^{-1} in both treatments. In the present study, a low feed conversion ratio (FCR) was observed, ranging from 0.83-1.28, particularly a significantly lower FCR was observed in treatment A than that in treatment B ($P > 0.05$).

Table 1. Growth performance of Nile tilapia in treatments A and B over the culture period of 160 days.

Parameters	Treatment A (fertilization plus feeding)	Treatment B (fertilization followed by feeding)
STOCKING		
Density (fish m^{-2})	3	3
Total Number	840	840
Mean Weight (g fish^{-1})	23±0.5	24±0.2
Total Weight (kg pond^{-1})	19.6±0.3	20.3±0.2
HARVEST		
Total Number	731±11	733±17
Survival rate (%)	87.0±1.3	87.3±2.0
Mean weight (g fish^{-1})	312±1.8^{a}	248±17.5^{b}
Total Weight (kg pond^{-1})	227.8±4.4^{a}	182.4±16.9^{b}
Weight gain (kg pond^{-1})	208.2±4.5^{a}	162.1±17.0^{b}
DWG (g fish^{-1} day^{-1})		
for the 1st 80 days	0.96±0.19	0.88±0.28
for the 2nd 80 days	2.66±0.19^{a}	1.96±0.33^{b}
for the entire culture cycle	1.81±0.01^{a}	1.42±0.22^{b}
Net Yield (t ha^{-1} year^{-1})	16.7±0.4^{a}	13.0±1.4^{b}
FCR	0.87±0.05^{a}	1.10±0.10^{b}

Mean values with different superscripts in the same row are significantly different at $P < 0.05$.

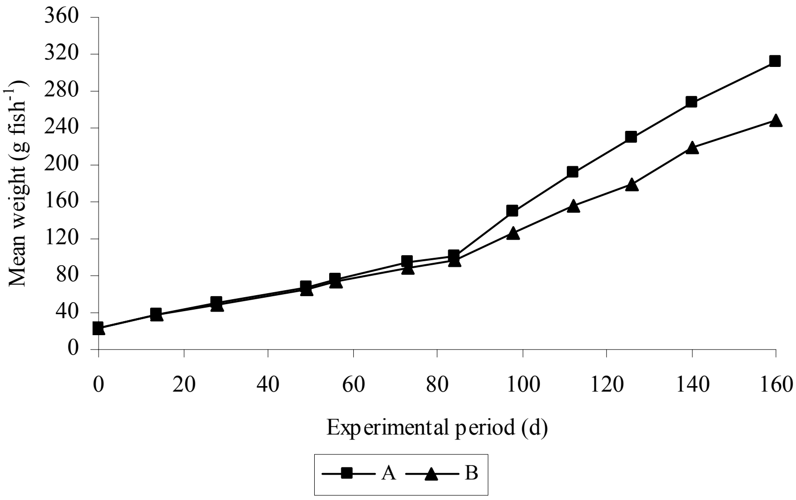

Figure 1. Mean body weight of Nile tilapia in treatments A (fertilization plus feeding) and B (fertilization followed by feeding) over the culture period.

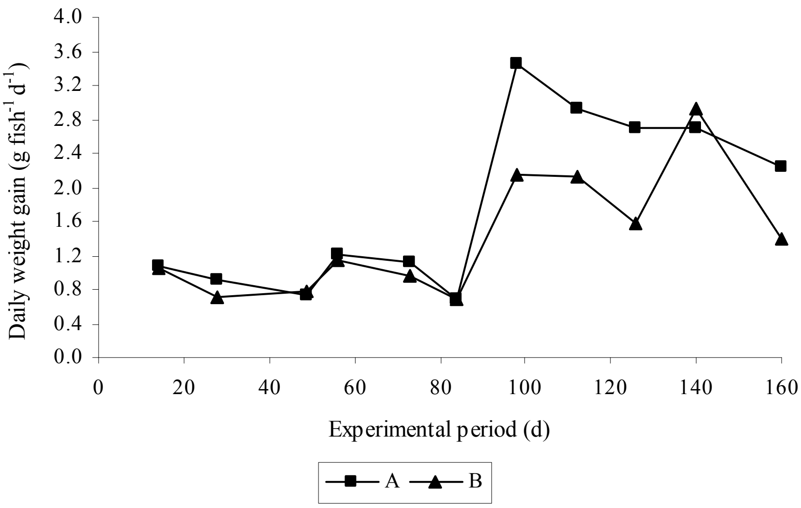

Figure 2. Mean daily weight gain of Nile tilapia in treatments A (fertilization plus feeding) and B (fertilization followed by feeding) over the culture period.

Among measured water quality parameters (Table 2), DO values of both treatments were most variable ranging from 1.0-10.6 mg L^{-1} with occasional drop below 0.5 mg L^{-1} towards the end of culture cycle (Fig. 3). Water temperatures ranged from 21.3 - 30.3 C over the culture period with an average of 27.4C. Values of pH fluctuated between 7.0 and 8.6 in both the treatments, and average pH values was 8.0 and 7.9 in treatments A and B, respectively, and was not significantly different between treatments ($P > 0.05$). Mean total alkalinity values in treatments A and B was 104±21.7 and 88±2.4 mg L^{-1} as $CaCO_3$, respectively. The highest alkalinity was observed in the first week of the study in both treatments, and thereafter showed a declining trend towards the end of the experimental period (Fig. 4). Mean TAN concentrations in both treatments A and B were 0.72±0.31 and 0.24±0.03 mg L^{-1}, respectively, and significantly higher TAN concentration was observed in treatment A than in treatment B towards the end of the culture period ($P < 0.05$; Fig. 5). TKN and TP concentrations in treatments A and B fluctuated with similar trend and remained in the similar range from beginning up to week 13 of the study, but, thereafter, higher TKN and TP levels were observed in treatment A than treatment B (Figs. 6 and 7). Mean concentration of chlorophyll *a* in treatments A and B was 140±36.2 and 111±15.5 µg L^{-1}, respectively, and chlorophyll *a* showed relatively stable trend in both treatments in the later half of the culture period (Fig. 8). Moreover, concentration of chlorophyll *a* was significantly higher in treatment A than in treatment B at all the samplings from week 15 (after commencement of artificial feeding) till the end of culture ($P < 0.05$). Statistical analysis showed that there were no significant differences for overall mean concentrations of TKN, TP and chlorophyll *a* between the two treatments ($P > 0.05$). The results of this experiment showed that the different feeding schemes in treatments A and B did not significantly ($P > 0.05$) affect major water quality parameters.

Table 2. Mean values of water quality parameters in treatment A and B over the culture period of 160 days.

Variable	Treatment A (fertilization plus feeding)	Treatment B (fertilization followed by feeding)
DO (mg L^{-1}) at dawn	3.5±0.3	3.5±0.2
Temperature (C)	27.4±1.4	27.4±1.4
pH (range)	7.0-8.7	7.4-8.6
Total alkalinity (mg L^{-1} as $CaCO_3$)	104±21.7^{a}	88±2.4^{b}
TKN (mg L^{-1})	5.6±0.3	4.4±0.2
TAN (mg L^{-1})	0.72±0.31^{a}	0.24±0.03^{b}
NO_2-N (mg L^{-1})	0.13±0.02	0.06±0.02
TP (mg L^{-1})	0.57±0.09	0.50±0.06
SRP (mg L^{-1})	0.07±0.03	0.07±0.02
Chlorophyll *a* (µg L^{-1})	140±36.2	111±15.5
TSS (mg L^{-1})	151±19.1	154±20.2
TVS (mg L^{-1})	45±11.1	42±2.3
Secchi disk visibility (cm)	14.1±1.2	12.8±1.5

Mean values with different superscripts in the same row are significantly different at $P < 0.05$.

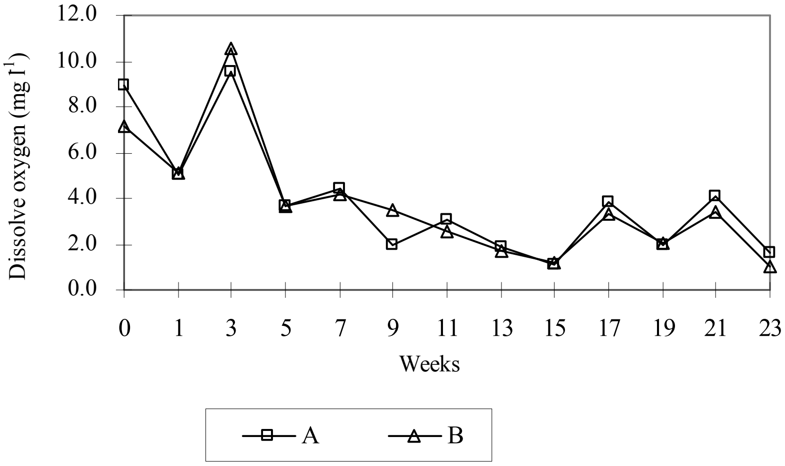

Figure 3. Fluctuation of DO at dawn in treatments A (fertilization plus feeding) and B (fertilization followed by feeding) over the culture period.

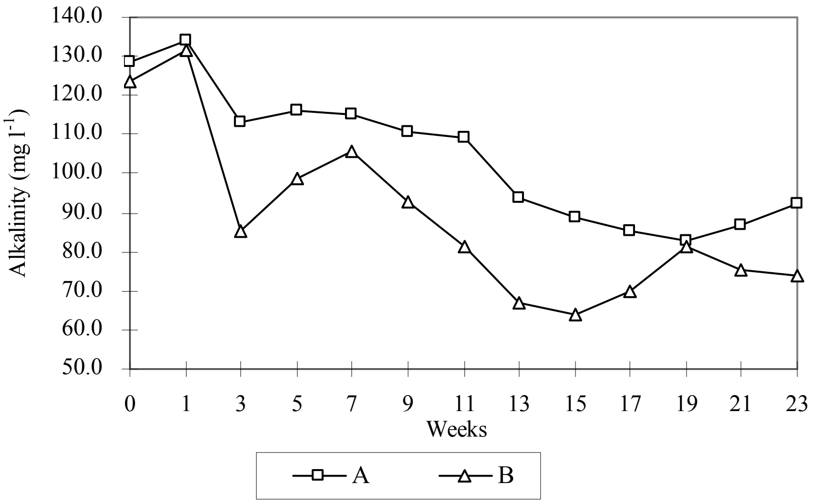

Figure 4. Fluctuation of total alkalinity in treatments A (fertilization plus feeding) and B (fertilization followed by feeding) over the culture period.

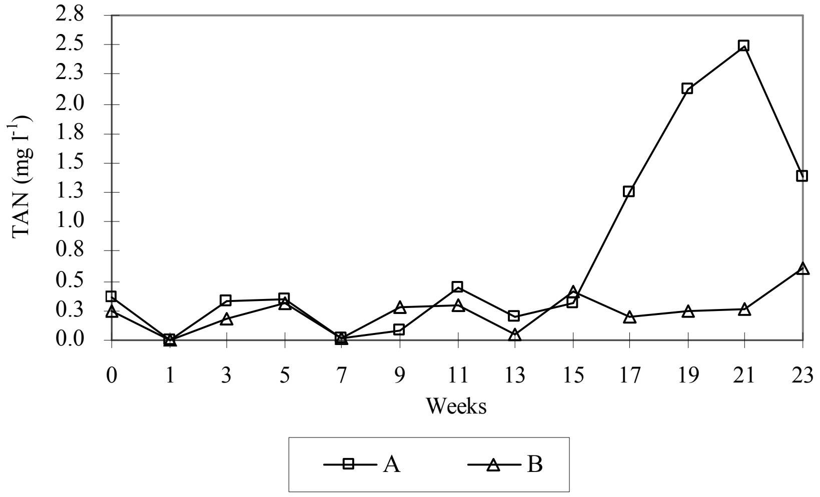

Figure 5. Fluctuation of TAN in treatments A (fertilization plus feeding) and B (fertilization followed by feeding) over the culture period.

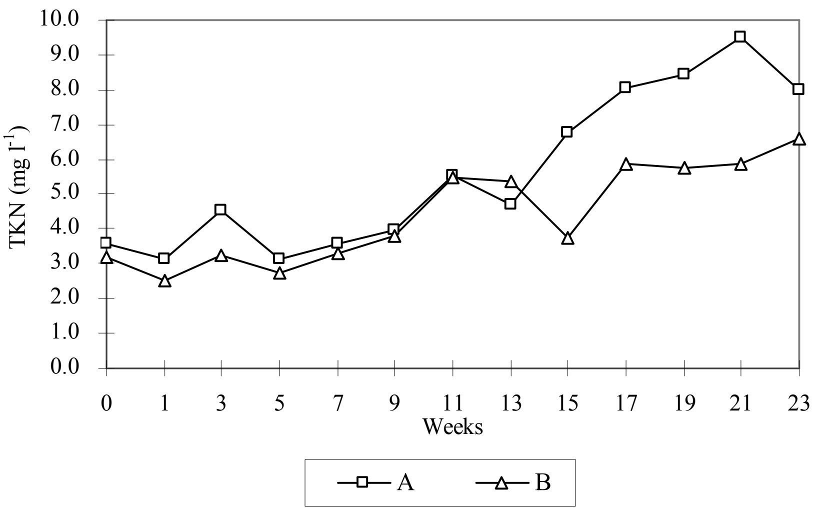

Figure 6. Fluctuation of total Kjeldahl nitrogen in treatments A (fertilization plus feeding) and B (fertilization followed by feeding) over the culture period.

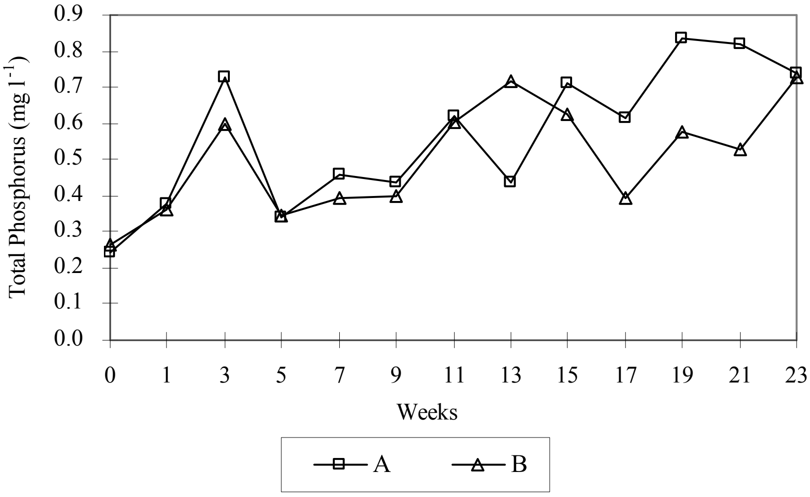

Figure 7. Fluctuation of total phosphorus in treatments A (fertilization plus feeding) and B (fertilization followed by feeding) over the culture period.

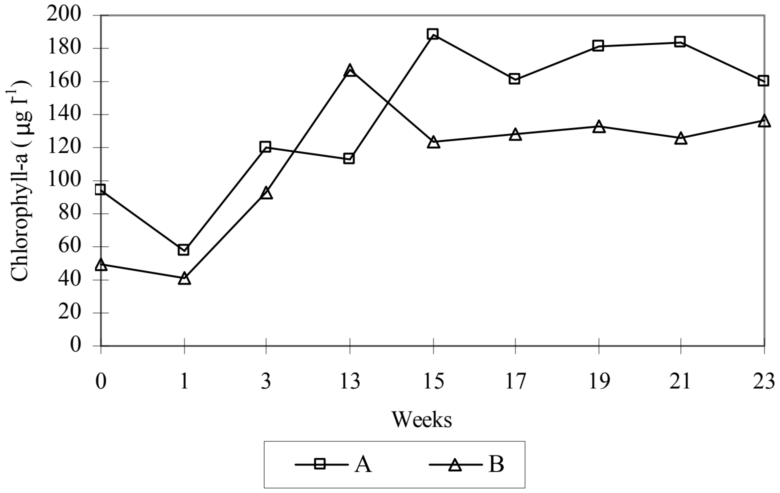

Figure 8. Fluctuation of chlorophyll *a* in treatments A (fertilization plus feeding) and B (fertilization followed by feeding) over the culture period.

A nutrient budget for total N and P inputs through fertilizer and feed and nutrient recovery in the harvested biomass over the course of the experiment is presented in Table 3. The estimated nutrient (N and P) inputs showed that fertilizer was the major source of nitrogen and phosphorus accounting for 68.1 and 53.7% N as well as 69.6 and 55.5% P in treatments A and B, respectively of the total added inputs through fertilizer and feed. The total added inputs of N and P were significantly higher in treatment A than that in treatment B. Harvested fish removed 16.8-20.1% N and 13.6 -14.10% P of the total inputs, and there were no significant difference between treatments. In the study, mean N and P wastage over the culture period were 79.9-83.2% N and about 86% P of the total inputs in the form of fertilizer, and feed and were not significantly different between treatments.

Table 3. Comparison of nitrogen and phosphorus inputs in the forms of fertilizer and feed, gain in the form of harvested biomass, and waste generated in treatments A and B over the culture period of 160 days.

Treatments	Treatment A (fertilization plus feeding)	Treatment B (fertilization followed by feeding)
Nitrogen (kg pond^{-1})		
Inputs		
Fertilizer	17.99 ± 0.00 (68.1)	9.38 ± 0.00 (53.7)
Feed	8.41 ± 0.41 (31.9)	8.07 ± 0.27 (46.3)
Total	26.40 ± 0.26 (100)	17.45 ± 0.23 (100)
Gain in harvested biomass	4.43 ± 0.19 (16.8)	3.59 ± 0.23 (20.1)
Waste	21.97 ± 0.32 (83.2)	13.86 ± 0.27 (79.9)
Phosphorus (kg pond^{-1})		
Inputs		
Fertilizer	4.60 ± 0.00 (69.6)	2.40 ± 0.00 (55.6)
Feed	2.00 ± 0.10 (30.3)	1.92 ± 0.06 (44.4)
Total	6.60 ± 0.09 (100)	4.32 ± 0.05 (100)
Gain in harvested biomass	0.90 ± 0.11 (13.6)	0.61 ± 0.03 (14.1)
Waste	5.86 ± 0.11 (86.4)	3.71 ± 0.05 (85.9)

Values in the parentheses are the percentages of total nutrient inputs.

Primary input in both treatments was feed, followed by fingerling and fertilizer (Table 4). Feed cost was not significantly different between treatments, and constituted 78.4% and 82.7% of the total variable cost in treatments A and B, respectively. Urea and TSP represented 5.7% and 6.0% of the total variable cost in treatment A, which was significantly higher than that in treatment B ($P < 0.05$) as Urea and TSP accounted for 3.3% and 3.4% of the variable cost, respectively in treatment B. The total variable cost in treatments A and B was $4,145.8 ha^{-1} crop^{-1} and $3,770.2 ha^{-1} crop^{-1}, respectively, and was not significantly different between treatments ($P > 0.05$). The estimated gross revenue from the sale of the fish was $4,880.7 ha^{-1} crop^{-1} in treatment A, which was significantly higher than that obtained in treatment B ($P < 0.05$, Table 4). Net return in treatments A and B was $734.9 ha^{-1} crop^{-1} and -$512.5 ha^{-1} crop^{-1}, respectively. The result showed that treatment B was economically unviable for culturing Nile tilapia as it resulted in negative return.

Table 4. Economic analysis to compare economic returns from two fertilization and feeding strategies (Unit: US $ ha^{-1} $crop^{-1}$).

Items	Treatment A (fertilization plus feeding)	Treatment B (fertilization followed by feeding)
Gross revenue	4,880.7 ± 93.4[a]	3,257.7 ± 301.1[b]
Variable cost		
Tilapia fingerlings	270.0 ± 0.0 (6.5)	270.0 ± 0.0 (7.2)
Urea	237.4 ± 0.0[a] (5.7)	123.9 ± 0.0[b] (3.3)
TSP	246.4 ± 0.0[a] (6.0)	128.6 ± 0.0[b] (3.4)
Feed	3,251.5 ± 157.9 (78.4)	3,120.7 ± 104.8 (82.7)
Cost of working capital	140.5 ± 5.5 (3.5)	127.7 ± 3.5 (3.4)
Total	4,145.8 ± 163.5 (100)	3,770.2 ± 108.5 (100)
Net return	734.9 ± 102.6[a] (17.9)	-512.5 ± 206.4[b] (-13.9)

Values in the parentheses are percentages of the total cost. Mean values with different superscripts in the same row are significantly different.

Discussion

Major water quality parameters measured during the study remained in the favorable range for tilapia (Boyd, 1990), suggesting that tilapia growth performance was not limited by any of the water quality parameters. It was noted that despite occasional drop in early morning DO level below 0.5 mg L^{-1} tilapia growth rate observed in the present study was comparable to the growth rate reported previously (Diana *et al*., 1994a; Diana *et al*., 1996). The result supports the findings of Liti *et al*. (2002) that Nile tilapia can tolerate low DO levels so that low DO levels at dawn did not significantly affect tilapia growth. Green (1992) also observed that occasional low DO levels did not affect tilapia growth. Lower alkalinity was observed in the treatment with fertilization followed by feeding than in the treatment with fertilization plus feeding throughout the experiment period, which might be due to the high rate of CO_2 production in the treatment with fertilization plus feeding than that in the treatment fertilization followed by feeding. Knud-Hansen (1998) mentioned that long term increase in alkalinity in ponds treated with organic matter has been associated with the release of CO_2 from the decomposition of organic material. A greater feed inputs and abundance of natural food in the treatment with fertilization plus feeding than those in the treatment with fertilization followed by feeding is likely to bring higher organic matter loading in the treatment with fertilization plus feeding and, thus, increased decomposition of organic matter. Higher TAN concentration in the treatment with fertilization plus feeding than the treatment with fertilization followed by feeding, particularly during the later half of the culture period, could be attributed to the higher loading rate in the treatment with fertilization plus feeding than in the treatment with fertilization followed by feeding in the form of uneaten feed, die-off planktons and other organic matter; organic matter settled to the pond bottom is mineralized by microbial activities to inorganic nutrients such as ammonia which stimulate algal growth in ponds (Boyd, 1985). TKN and TP concentrations fluctuated widely over the study period, but showed almost identical trend in both treatments, particularly increasing trend was observed in the later half of the culture period, indicating nutrient build-up in the water column with the progress of rearing. Concentration of chlorophyll *a* in both treatments registered sharp increase in the first half of the culture period and a relatively stable concentration in the later half of the culture period. This is to note that chlorophyll-a concentration peaked in both the treatments after the initiation of feeding, but a greater increase was recorded in the treatment with fertilization plus feeding than in the treatment with fertilization followed by feeding. The result suggested that in tilapia grow-out system feeding combined with regular fertilization could lead to a higher natural pond productivity and sustain a larger plankton biomass than feeding only as nutrient input. Green (1992) also reported changes in primary production when fertilization and feeding was done. Diana *et al.* (1996) emphasized that the efficient use of supplementary feed at a limited rate, along with fertilizer and natural feeds does not adversely affect water quality.

Growth of tilapia in the first 80 day, under fertilization, was 0.96 g d^{-1} and 0.88 g d^{-1}, respectively and was not significantly different between the two treatments. Once feeding commenced, accelerated growth rate was observed in both treatments. During an experiment that utilized staged feeding (Diana *et al.*, 1996), fish growth differentiated soon after the first feeding was initiated. The result supports the contention of Diana *et al.* (1996) that the critical standing crop (CSC) had already been reached at that level of fertilization. Furthermore, in the present study a greater increase in growth rate was observed in treatment A, which continued regular fertilization in addition to the 50% satiation feeding, as compared to treatment B with feed as the only nutrient inputs. The result suggested that 50 % satiation feeding alone may not be enough to support the high growth rate of fish and the nutrients (N and P) present in the ponds were not sufficient to support high plankton production to supplement tilapia growth. Growth rate observed in this study was comparable to the growth reported earlier (Zonneveld and Fadholi, 1991; Green, 1992; Diana *et al.*, 1994a). Diana *et al.* (1996) reported a slightly higher growth of tilapia under optimal fertilization (1.17 g/d) and under fertilization plus feeding (3.10 g d^{-1}) as compared to the growth observed in the present study. Moreover, in the present study a relatively lower growth rate observed in the treatment with fertilization followed by feeding (1.96 g d^{-1}) during the second 80 day of culture, might be due to the low abundance of natural food to supplement tilapia growth in such ponds as reflected by lower concentration of chlorophyll *a* in the treatment with fertilization followed by feeding than in the treatment with fertilization plus feeding. Low FCR in this study confirms that the fish growth benefited from natural foods stimulated by fertilization. Green (1992) reported that fish production at El Caro, Honduras was 5,305 kg/ha in 150 days, and the feed conversion ratio was 1.8 when feed (24% crude protein) was the only input offered to tilapia stocked at 2 fish m^{-2}. Furthermore, the author observed that the natural productivity stimulated by pond fertilization was sufficient to permit rapid fish growth during the first two months of culture. Net annual fish yield (10.4 - 17.2 t ha^{-1}) obtained in the present study was higher than previously reported by Diana *et al.* (1994b), wherein fish yield between 8,400 and 11, 600 kg ha^{-1} y^{-1} in a fertilizer and supplemental feeding combination feed at 50% *ad libitum*.

In the present study proportional nutrient recovery in the harvested tilapia was 16-20% N and 14% P of the total inputs through fertilizer and feed, which was slightly lower than the values reported previously for hybrid tilapia (Siddqui and Al-Harbi, 1999). Moreover, accounting of nutrient waste generated in producing 1 kg tilapia (nutrient waste/harvested biomass) revealed that in the present study treatment B was more nutrient efficient than treatment A; treatment A generated 97.4 g N and 25.7 g P waste as compared to 76.0 g N and 20.3 g P waste generated in treatment B. This might be attributable to the higher total nutrient inputs in treatment A (1.5 times) than in treatment B, indicating that a culture system with high nutrient input is likely to be less nutrient efficient. Siddqui and Al-Harbi (1999) reported that production of one kilogram of hybrid tilapia lead to the release of 87.1-95.6 g nitrogen and 12.6-13.8 g phosphorus into the water, as metabolic waste.

The income was estimated by a simple analysis. Fixed costs were not included in the analysis as the analysis was intended to only compare relative difference in efficiency between the treatments, and we assumed those to be similar for both treatments. The cost estimation was based on local market prices of fingerling, fertilizer, feed, and fish. In this study feed represented the greatest level of inputs in both treatments. The total variable cost of production was not significantly different between treatments, but the gross revenue generated by selecting fertilization plus feeding (treatment A) was significantly higher than the practice of fertilization followed by feeding (treatment B). Though the cost of growing tilapia in the treatment with fertilization plus feeding was merely 10% more than the cost incurred in the treatment with fertilization followed by feeding, the gross revenue generated differed by about 50% (Table 4). The results of the study showed a significant increase in net income in culturing tilapia under fertilization plus feeding as compared to culturing tilapia under feeding only. In the present study, negative net return obtained in the treatment with fertilization followed by feeding was due to the low production caused by poor growth performance of tilapia in the treatment. This study demonstrated that fertilization plus formulated diet produced higher yield than formulated diet only, and, hence, the practice of fertilization plus feeding is more cost-effective than using fertilization followed by feeding for Nile tilapia culture. The results of the study supports the view of Engle *et al.* (2002) that the yield of tilapia in the high-input monoculture system was a determining factor in its selection in the profit-maximizing production activities. Further to this accounting of the cost to produce 1 kg tilapia revealed that unit production cost was lower in the treatment with fertilization plus feeding (\$0.50 kg^{-1} fish) than that in the treatment with fertilization followed by feeding (\$0.62 kg^{-1} fish), suggesting that production costs can be significantly reduced in a tilapia farming system where an efficient fertilization program is applied. As costs of fertilizer is much less than feed, better feed conversion ratio in fertilization plus feeding treatments were reflected in feed costs saving and thus, an increased net return.

In conclusion, tilapia growth was better in the treatment with fertilization plus feeding than the treatment with fertilization followed by feeding. The study suggested that maximizing production efficiency would require the combination of the two nutrient input sources, where addition of fertilizer can boost the natural food production in the pond and ultimately the fish growth.

Acknowledgement

The authors wish to thank Mr. Y. Manoj and Mr. P. Supat for their field and laboratory assistance. This research is a component of the Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP) supported by the US Agency for International Development, Grant No. DAN-4023-G-00-0031-00, and by contributions from the University of Michigan, the Royal Thai Department of Fisheries, and the Asian Institute of Technology. This is PD/A CRSP Accession No. 1277. The opinions expressed herein are those of the authors and do not necessarily reflect the views of the US Agency of International Development.

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