STRATEGIES FOR NILE TILAPIA (*OREOCHROMIS NILOTICUS*) POND CULTURE

YANG YI[1] AND JAMES DIANA[2]

1. *College of Fisheries and Life, Shanghai Ocean University, Shanghai, China yiyang@shou.edu.cn*
2. *School of Natural Resources and Environment, University of Michigan , Ann Arbor, Michigan 48109-1115, USA*

Abstract

Different strategies for Nile tilapia (*Oreochromis niloticus*) culture in ponds with a series of progressive inputs were compared. The sequential experimental stages to increase fish production through intensification were: 1) triple superphosphate (TSP) only; 2) chicken manure only; 3) chicken manure supplemented with urea or urea and TSP; 4) urea and TSP; 5) continually supplemental feeding; 6) staged supplemental feeding; 7) feeding alone.

The results showed that the choices of input regimes with increasing economic gains are: 1) fertilizing ponds with moderate loading of chicken manure; 2) fertilizing ponds with chicken manure supplemented with urea and TSP; 3) fertilizing ponds with urea and TSP; 4) fertilizing ponds initially with urea and TSP in combination of supplemental pelleted feed at 50% satiation level at later stage of grow-out cycle.

Keywords: Nile tilapia, pond culture, fertilization, feeding

INTRODUCTION

Pond fish culture can be practiced at many levels of production intensity based on the quantity and quality of nutrients added to enhance, supplement, or replace natural pond productivity (Bardach *et al.* 1972). In many parts of the world, the traditional practice in rural pond aquaculture depends primarily upon on-farm inputs from livestock and domestic wastes. In the low-cost systems, fish production is normally limited as the quality and quantity of pond inputs are often low. To increase pond carrying capacity, off-farm inputs such as chemical fertilizers and supplementary feeds are required. However, increase in fish biomass and yield through greater pond inputs may eventually reach the point of diminishing returns in economic terms. Nile tilapia (*Oreochromis niloticus*) culture in Southeast Asia has been expanded rapidly and intensified. In Thailand, Nile tilapia production in the mass commercial scale is normally done in semi-intensive earthen ponds. Meanwhile there are ongoing efforts to promote low-input production strategies for small-scale farmers in Thailand, Vietnam, Laos, and Cambodia (Szyper *et al.* 1995). For more than two decades, the Aquaculture Collaborative Research Support Program (ACRSP) in Thailand has conducted sequentially staged experiments to increase Nile tilapia production through intensification by increasing nutrient inputs and stocking densities (Diana 1997; Lin *et* *al.* 1997). The ACRSP has developed various Nile tilapia culture strategies for small-scale farmers with various resources and financial affordability.

In study of aquaculture, economic research is often neglected by aquaculturists, although it is regarded as of primary importance (Shang 1990). Economic analysis is essential to evaluate the viability of investment in aquaculture, to determine efficiency of resource allocation and management practices, and to evaluate usefulness of new culture technology.

The purposes of this study are to assess the economic returns in staged increment of pond inputs in Nile tilapia culture and to recommend the appropriate profitable strategies to small-scale farmers with various resources and financial affordability based on partial budget analyses.

MATERIALS AND METHODS

The data used in this study were collected from a series of experiments conducted in Thailand during the period from 1984 through 1996. The experiments were based on systematic increments of pond inputs through the following sequential stages to increase fish production:

Stage 1 "TSP only" input: fertilizing ponds with triple superphosphate (TSP) only at a rate of 8 kg $P_2O_5 \cdot ha^{-1} \cdot month^{-1}$ or 17.8 kg $TSP \cdot ha^{-1} \cdot month^{-1}$ (Diana et al. 1987);

Stage 2 "Chicken manure only" input: fertilizing ponds with chicken manure (CM) only at rates of 125, 250, 500, and 1,000 kg dry matter $(DM) \cdot ha^{-1} \cdot week^{-1}$ (Anon. 1988; Diana et al. 1990);

Stage 3 "Chicken manure supplemented with urea or urea and TSP" input: fertilizing ponds with chicken manure at 44, 100, and 200 kg $(DM) \cdot ha^{-1} \cdot week^{-1}$ supplemented with urea to bring nitrogen (N) to phosphorus (P) ratio to 5:1 (Batterson *et al.* 1990); or fertilizing ponds with chicken manure at 25, 75, 125, 175, and 225 kg $(DM) \cdot ha^{-1} \cdot week^{-1}$ supplemented with urea and TSP to give 28 kg N and 7 kg $P \cdot ha^{-1} \cdot week^{-1}$, bringing N:P ratio to 4:1 (Knud-Hansen *et al.* 1991).

Stage 4 "Urea and TSP" input: fertilizing ponds with urea and TSP at rates of 28 kg N and 7 kg $P \cdot ha^{-1} \cdot week^{-1}$ (Diana *et al.* 1994; Szyper and Hopkins 1995);

Stage 5 "Continually supplemental feeding" input: fertilizing ponds with urea and TSP at 28 kg N and 7 kg $P \cdot ha^{-1} \cdot week^{-1}$ supplemented with pelleted feed at 25%, 50%, and 75% satiation feeding levels (Diana *et al.* 1994, 1996a); or adjusting fertilization rates of urea and TSP weekly based on N and P contents in wastes derived from fish feeding to give 28 kg N and 7 kg $P \cdot ha^{-1} \cdot week^{-1}$ (Diana *et al.* 1997);

Stage 6 "Staged supplemental feeding" input: fertilizing ponds with urea and TSP at rates of 28 kg N and 7 kg P·ha^{-1}·week^{-1} supplemented with pelleted feed at 50% satiation level starting feeding at 50, 100, 150, 200, and 250 g size (Diana *et al.* 1996b);

Stage 7 "Feeding alone": feeding Nile tilapia with pelleted feed at 100% satiation level (Diana *et al.* 1994).

All experiments were conducted in earthen ponds with surface areas of 200-400 m^2 and water depth of around 1 m. Stocking density in those experiments ranged from 0.88 to 9 fish·m^{-2}, and culture period was generally 5 months with exceptions in some supplemental feeding experiments. There was no water exchange in all experimental ponds, except weekly water additions to make up evaporation and seepage losses. Fish yields were standardized to the unit of kg·ha^{-1}·year^{-1}, extrapolated from two 5-month culture cycles per year. Gross fish yields (GFY) and net fish yields (NFY) for all input regimes of the above seven sequential experimental stages were presented in Table 1.

Partial budget analyses were performed for all input regimes. Facility and labor costs were not included, because we only intend to compare the profitability of alternative strategies for small-scale Nile tilapia culture involving family labor only. The material costs and fish sales were based on local market prices in Thailand in 1996. Feed price was \$0.50 kg^{-1}, urea \$0.24 kg^{-1}, TSP \$0.36 kg^{-1}, chicken manure \$0.024 kg^{-1} (wet weight), and sex-reversed fry \$0.009 each. Market values of adult Nile tilapia varied with size: \$0.20 kg^{-1} for fish below 100 g, \$0.48 kg^{-1} for fish between 100-299 g, \$0.60 kg^{-1} for fish between 300-499 g, and \$0.80 kg^{-1} for fish above 500 g. The profitability of various input regimes was compared in terms of total production cost (including costs of fertilizers, chicken manure, feed and fry), gross revenue (from selling fish), net revenue (gross revenue - cost), unit cost (cost to produce 1 kg of net fish yield) and R/C ratio (a ratio of gross revenue to total production cost).

Sensitivity analysis was carried out to evaluate relative magnitudes of the effects of price changes of inputs and outputs on the profitability of each input regime by comparing the percentage of changes in net revenue when varying price of each input and output by 10% about the fixed prices.

RESULTS

Net revenues were positive for 26 out of 33 input regimes tested for Nile tilapia culture, but varied with different input regimes (Table 2). Generally, R/C ratio decreased from 4.7 to 0.8 with increasing intensification levels through increasing inputs and stocking densities. Unit cost ranged from \$0.12 to 0.74 kg^{-1} net fish yield, with the lowest value in "chicken manure only" input and the highest in "feeding alone" input.

The "TSP only" input produced minimal fish yield and the smallest harvested fish size, giving marginal net revenue. In the "chicken manure only" input, all input regimes except for the one with the highest stocking density had positive net revenue, which decreased with increasing manuring rates and stocking densities. The highest net revenue and lowest unit cost were achieved in the input regimes of manuring rate of 125 and 250 kg (DM) $\cdot ha^{-1} \cdot week^{-1}$. All input regimes of "chicken manure supplemented with urea or urea and TSP" input produced positive net revenue. When chicken manure was supplemented with urea to give a 5:1 of N: P ratio, net revenues increased with increasing rates of both chicken manure and urea. However, when the rates of N and P were fixed to 28 kg N and 7 kg $P \cdot ha^{-1} \cdot week^{-1}$, net revenues increased with decreasing manure and increasing inorganic fertilization rates. But they decreased after reaching the peak at the chicken manure rate of 75 kg (DM) $\cdot ha^{-1} \cdot week^{-1}$ supplemented with urea and TSP. With the "urea and TSP" input, the balanced input regime at rates of 28 kg N and 7 kg $P \cdot ha^{-1} \cdot week^{-1}$ produced positive net revenues at either low or high stocking densities, with the highest net revenue achieved in ponds stocked at 2.7 $fish \cdot m^{-2}$. In the "continually supplemental feeding" input, only the input regimes with less than 50% satiation feeding level and tilapia stocked at low densities (2.7 and 3 $fish \cdot m^{-2}$) produced positive net revenues. The highest value was achieved from the ponds fertilized at balanced rates and stocked at 3 $fish \cdot m^{-2}$.

However, this was similar to that achieved in the "chicken manure supplemented with urea or urea and TSP" and "urea and TSP" inputs. For "staged supplemental feeding" input, positive net revenues were achieved in all input regimes. The net revenue reached \$5,029 $ha^{-1} \cdot year^{-1}$ when fish were fed at 50% satiation level starting feeding at 100 g size, which was the highest net revenue among all tested input regimes. The "feeding alone" input was not profitable.

Table 1. Fish growth performance for 7 stages of pond input regimes based on the PD/A CRSP experiments in Thailand.

Input regimes	Stocking density (fish·m^{-2})	Culture period (days)	Final Size (g)	Gross fish yield (kg^{-1}·ha^{-1}·yr^{-1})	Net fish yield (kg^{-1}·ha^{-1}·yr^{-1})
Stage 1					
TSP (17.8)	1	156	73	1,380	750
Stage 2					
CM(125)	0.88	150	179	2,965	2,502
CM(250)	0.88	150	209	3,266	2,801
CM(500)	0.88	150	214	3,455	2,980
CM(500)	1	150	177	2,859	2,278
CM(500)	2	150	108	3,469	2,299
CM(500)	3	150	76	3,595	1,899
CM(1000)	0.88	150	240	3,935	3,463
Stage 3					
CM(44)+urea(N:P=5:1)	0.88	150	133	2,048	1,842
CM(100)+urea(N:P=5:1)	0.88	150	170	2,555	2,349
CM(200)+urea(N:P=5:1)	0.88	150	287	4,238	4,031
CM(225)+urea(28N)+TSP(7P)	1.76	147	178	4,996	4,686
CM(175)+urea(28N)+TSP(7P)	1.76	147	168	5,143	4,838
CM(125)+urea(28N)+TSP(7P)	1.76	147	203	6,237	5,935
CM(75)+urea(28N)+TSP(7P)	1.76	147	253	7,578	7,271
CM(25)+urea(28N)+TSP(7P)	1.76	147	187	5,518	5,227
Stage 4					
Urea(28N)+TSP(7P)	2	150	136	4,476	3,958
Urea(28N)+TSP(7P)	2.7	155	149	7,110	6,439
Stage 5					
Feed(25%)+urea(28N)+TSP(7P)	2.7	155	250	12,106	11,425
Feed(50%)+urea(28N)+TSP(7P)	2.7	155	388	18,374	17,714
Feed(75%)+urea(28N)+TSP(7P)	2.7	155	403	21,053	20,366
Feed(50%)+urea(28N)+TSP(7P)	3	146	447	22,936	21,878
Feed(50%)+urea+TSP(varied)	3	194	523	20,144	19,448
Feed(50%)+urea(28N)+TSP(7P)	6	146	304	26,044	23,855
Feed(50%)+urea+TSP(varied)	6	194	445	31,718	30,260
Feed(50%)+urea(28N)+TSP(7P)	9	146	272	31,290	27,959
Feed(50%)+urea+TSP(varied)	9	194	323	25,836	23,639
Stage 6					
Feed(50%, 50g)+urea(28N)+TSP(7P)	3	236	592	19,571	19,012
Feed(50%, 100g)+urea(28N)+TSP(7P)	3	236	596	19,539	18,952
Feed(50%, 150g)+urea(28N)+TSP(7P)	3	265	533	15,192	14,680
Feed(50%, 200g)+urea(28N)+TSP(7P)	3	305	627	13,376	12,944
Feed(50%, 250g)+urea(28N)+TSP(7P)	3	328	488	11,848	11,439
Stage 7					
Feed (100%)	2.7	155	416	19,574	18,901

Table 2. Results of partial budget analyses for 7 stages of pond input regimes based on the PD/A CRSP experiments in Thailand.

Input regimes	Stocking density (fish·m^{-2})	Gross revenue (\$·ha^{-1}·yr^{-1})	Cost (\$·ha^{-1}·yr^{-1})	Net revenue (\$·ha^{-1}·yr^{-1})	Unit Cost (\$·kg^{-1})	R/C Ratio
Stage 1						
TSP (17.8)	1	276	236	40	0.32	1.2
Stage 2						
CM(125)	0.88	1,423	306	1,117	0.12	4.7
CM(250)	0.88	1,568	454	1,114	0.16	3.5
CM(500)	0.88	1,659	750	909	0.25	2.2
CM(500)	1	1,372	750	622	0.33	1.8
CM(500)	2	1,665	908	757	0.40	1.8
CM(500)	3	719	1,067	-348	0.56	0.7
CM(1000)	0.88	1,889	1,341	548	0.39	1.4
Stage 3						
CM(44)+urea(N:P=5:1)	0.88	983	322	661	0.17	3.1
CM(100)+urea(N:P=5:1)	0.88	1,227	527	700	0.22	2.3
CM(200)+urea(N:P=5:1)	0.88	2,034	895	1,139	0.22	2.3
CM(225)+urea(28N)+TSP(7P)	1.76	2,398	1,482	916	0.32	1.6
CM(175)+urea(28N)+TSP(7P)	1.76	2,469	1,548	921	0.32	1.6
CM(125)+urea(28N)+TSP(7P)	1.76	2,994	1,637	1,357	0.28	1.8
CM(75)+urea(28N)+TSP(7P)	1.76	3,638	1,683	1,955	0.23	2.2
CM(25)+urea(28N)+TSP(7P)	1.76	2,649	1,751	898	0.33	1.5
Stage 4						
Urea(28N)+TSP(7P)	2	2,148	1,522	626	0.38	1.4
Urea(28N)+TSP(7P)	2.7	3,413	1,680	1,733	0.26	2.0
Stage 5						
Feed(25%)+urea(28N)+TSP(7P)	2.7	5,810	5,678	132	0.50	1.0
Feed(50%)+urea(28N)+TSP(7P)	2.7	11,025	9,474	1,551	0.53	1.2
Feed(75%)+urea(28N)+TSP(7P)	2.7	12,632	12,881	-249	0.63	1.0
Feed(50%)+urea(28N)+TSP(7P)	3	13,760	12,790	970	0.46	1.1
Feed(50%)+urea+TSP(varied)	3	16,115	14,331	1,784	0.59	1.1
Feed(50%)+urea(28N)+TSP(7P)	6	15,626	16,053	-427	0.52	1.0
Feed(50%)+urea+TSP(varied)	6	19,031	21,008	-1,977	0.55	0.9
Feed(50%)+urea(28N)+TSP(7P)	9	15,020	21,251	-6,231	0.58	0.7
Feed(50%)+urea+TSP(varied)	9	15,502	19,920	-4,418	0.65	0.8
Stage 6						
Feed(50%, 50g)+urea(28N)+TSP(7P)	3	15,657	12,636	3,021	0.66	1.2
Feed(50%, 100g)+urea(28N)+TSP(7P)	3	15,631	10,602	5,029	0.56	1.5
Feed(50%, 150g)+urea(28N)+TSP(7P)	3	12,153	8,889	3,264	0.61	1.4
Feed(50%, 200g)+urea(28N)+TSP(7P)	3	10,701	9,252	1,449	0.71	1.2
Feed(50%, 250g)+urea(28N)+TSP(7P)	3	7,108	6,544	564	0.57	1.1
Stage 7						
Feed(100%)	2.7	11,744	13,942	-2198	0.74	0.8

The relationship among production cost, net revenue, gross and net fish yields for the input regimes with the highest net revenue in each stage was shown in Figure 1. Progressively increasing nutrient inputs resulted in the increased both gross and net fish yields, and also caused corresponding increases of production cost. However, net revenue did not show the same pattern. For the fertilization inputs (stages 1, 2, 3 and 4), "chicken manure supplemented with urea and TSP" input (stage 3) gave the highest net revenue. Compared with "urea and TSP" input (stage 4), "continually supplemental feeding" input (stage 5) failed to resulted in higher net revenue. However, "staged supplemental feeding" input (stage 6) produced much higher net revenue than other inputs. "Feeding alone" input even resulted in the negative net revenue. Except "TSP only" input (stage 1), unit cost increased and R/C ratio decreased with progressively increasing nutrient inputs (Figure 2).

The relationship between input cost and net revenue can be expressed as $Y = -0.000000007X^3 + 0.00004X^2 + 0.4971X + 626.72$ ($R^2 = 0.66$) by using the data from the input regimes with the highest net revenue in each stage (Figure 3). It shows that net revenue increases with increasing input cost, and decreases when input cost increases further with increasing intensification.

Production cost analyses for the input regimes with the highest net revenue at each stage are summarized in Table 3. Among all inputs, "TSP only" and "chicken manure only" inputs had the lowest total production cost, of which the fry cost accounted for more than 50%. With progressively greater nutrient inputs, the larger proportion of total production cost came from inorganic fertilizers. When pelleted feed was supplemented to inorganically fertilized ponds, the feed cost accounted for more than 85% of the total production cost. But for the "feeding alone" input, the feed cost reached 96% of the total production cost.

The sensitivity of the net revenue to price changes of adult Nile tilapia and various inputs is presented in Table 4. The market prices of Nile tilapia and pelleted feed were generally the most sensitive factors affecting the net revenue. The price of chicken manure was the least sensitive factor for the inputs of either "chicken manure only" or "chicken manure supplemented with urea or urea and TSP", while the price of Nile tilapia fry was the least sensitive factor for the inputs without chicken manure, with an exception of "TSP only" input.

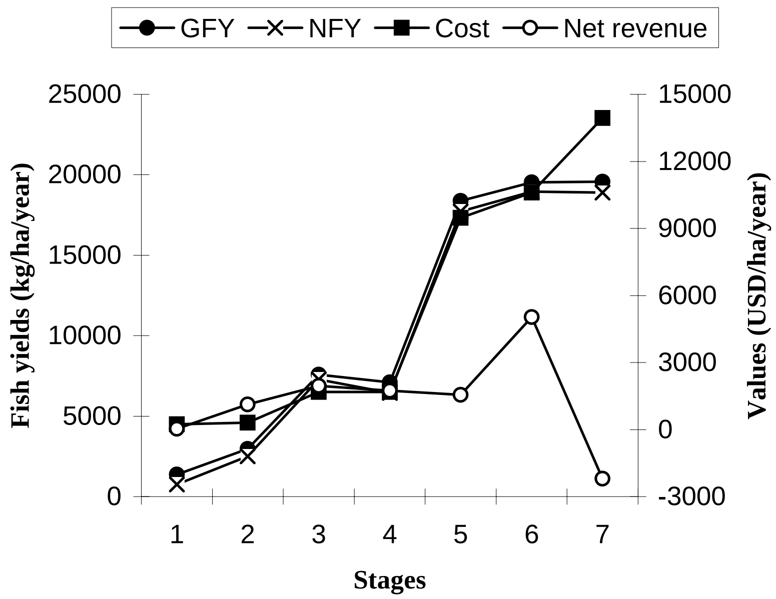

Figure 1. Relationships among cost, net revenue, gross and net fish yields in the input regimes with the highest net revenue in each stage.

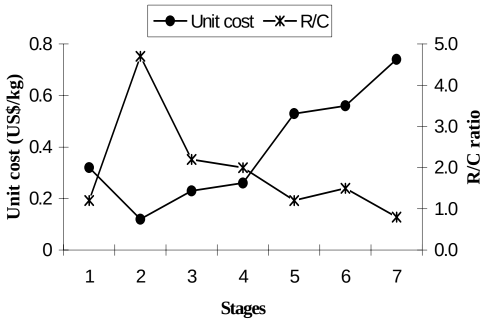

Figure 2. Changes of unit cost and R/C ratio with the increasing nutrient inputs from stages 1 to 7.

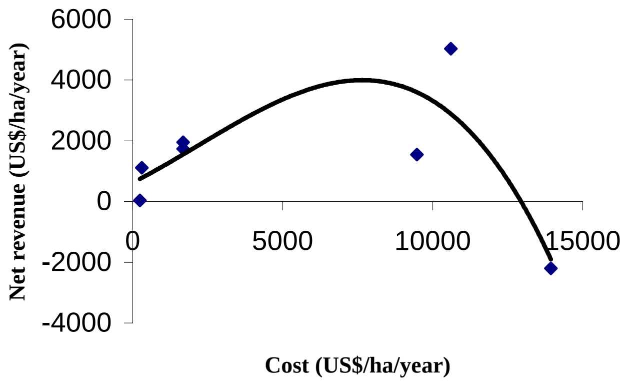

Figure 3. The relationship between input cost and net revenue.

Table 4. Sensitivity analysis of factors affecting net revenue for the input regimes with the highest net revenue in each stage. The data are the mean absolute percentages of net revenue changes when the prices of inputs and fish output change.

Input regimes	Adult Nile tilapia	Pelleted feed	Inorganic fertilizers	Chicken manure	Nile tilapia fry
Stage 1					
TSP (17.8)	69.58	----	15.95	----	43.63
Stage 2					
CM(125)	12.74	----	----	1.32	1.42
Stage 3					
CM(75)+urea(28N)+TSP(7P)	18.61	----	6.50	0.45	1.65
Stage 4					
Urea(28N)+TSP(7P)	19.69	----	6.68	----	5.75
Stage 5					
Feed(50%)+urea+TSP(varied)	90.31	73.70	4.27	----	2.34
Stage 6					
Feed(50%, 100g)+urea(28N)+TSP(7P)	31.08	18.10	2.30	----	0.68
Stage 7					
Feed(100%)	53.43	61.06	----	----	2.38

DISCUSSION

This study showed that progressively increasing inputs generally produced greater fish yields but did not result in the greater net revenue correspondingly. Production costs obviously limit the applicability of some developed strategies such as "staged supplemental feeding" for small-scale farmers. Despite limited potential for cash return, the low-input regimes such as "chicken manure only" can be attractive for those farmers who can not afford inorganic fertilizers, and can produce fish as food security from on-farm inputs for poor farmers. However, the "staged supplemental feeding" input produces the highest net revenue, generating income for those farmers who have good financial ability. Green *et al.* (1994) found that the highest net revenue was achieved in ponds manured at rates of 750 and 1,000 kg chicken manure$\cdot$ha$^{-1}\cdot$week^{-1} for Nile tilapia production in Honduras. However, it was achieved at much lower rates (125 and 250 kg$\cdot$ha$^{-1}\cdot$week^{-1}) in this study.

The market price of Nile tilapia is the most sensitive factor affecting net revenues. In general, the large Nile tilapia (> 500 g) can only be grown with feed inputs. The negative net revenue occurred in "continually supplemental feeding" input mainly because the fish were harvested at sizes less than 500 g, when the price of fish barely exceeded feed cost. If the feeding and growth rates were extrapolated to continue linearly until the fish reached 500 g (Diana *et al.*, 1996b), all input regimes in "continually supplemental feeding" input would also be profitable. Although large fish fetch higher prices, the feed consumption and price determine the profitability. Feed price is the second most sensitive factor affecting net revenues, and feed cost accounts for the highest proportion of total production cost in the "supplemental feeding" inputs. Therefore, further research is needed to fine-tune the "supplemental feeding" inputs and to develop low-cost pelleted feed in order to fetch high market prices of Nile tilapia, reduce feed cost and generate maximum profits.

In conclusion, this study may provide guidelines to small-scale tilapia farmers to maximize their returns from their limited resources and financial affordability. The choices with increasing economic gains are: 1) fertilizing ponds with moderate loading of chicken manure; 2) fertilizing ponds with chicken manure supplemented with urea and TSP to balance nutrient loading and maintain water quality; 3) fertilizing ponds with urea and TSP at appropriate rates; 4) fertilizing ponds initially with urea and TSP, in combination of supplemental pelleted feed at 50% satiation level at later stage of grow-out cycle.

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