A MANUAL OF FERTILIZATION AND SUPPLEMENTAL FEEDING STRATEGIES FOR SMALL-SCALE NILE TILAPIA CULTURE IN PONDS

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PREFACE

This study was conducted at the Asian Institute of Technology during January-June 2001 to summarize Aquaculture CRSP work on pond culture of Nile tilapia *Oreochromis niloticus* in Thailand and thus to develop a manual of fertilization and supplemental feeding strategies for small-scale Nile tilapia culture in ponds. The manual consists of eight sections.

1. Introduction
2. Nile Tilapia
3. Pond Preparation
4. Stocking
5. Fertilizers and Feed
6. Fertilization Strategies
7. Supplemental Feeding Strategies
8. Choosing Appropriate Strategies

The aims of the manual are to provide simple guidelines of fertilization and supplemental feeding for small-scale Nile tilapia pond culture and to provide extension and training materials to the main audiences of the manual, namely, extension workers, trainers and well-educated farmers. We expect that small-scale fish farmers in Asian countries, especially in Southeast and South Asia, will benefit from this manual to produce Nile tilapia through effectively using organic and inorganic fertilizers and feeds to increase fish production, achieve higher economic returns and reduce environmental impacts.

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1. INTRODUCTION

Pond fish culture can be practiced at many levels of production intensity based on quantity and quality of nutrients added to enhance, supplement, or replace natural pond productivity. 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 these 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 at a 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 Southeast Asia.

For almost two decades, the Southeast Asia Component of the Pond Dynamics/ Aquaculture Collaborative Research Support Program (PD/A CRSP) sponsored by USAID has conducted sequentially staged experiments to increase Nile tilapia production through intensification by increasing nutrient inputs and stocking densities in semi-intensive culture ponds. The PD/A CRSP has developed various Nile tilapia culture strategies for small-scale farmers with different resources and financial affordability, through the joint efforts of scientists at US universities (University of Michigan, Michigan State University, and University of Hawaii), Royal Thai Department of Fisheries, and the Asian Institute of Technology (AIT, Bangkok, Thailand).

2. NILE TILAPIA

2.1 General characteristics

Tilapias have been commonly cultured all over the world, and become one of the world's most important groups of cultured fish. Among all cultured tilapia species, Nile tilapia *Oreochromis niloticus* (Figure 1) has emerged as the single most important species. The attributes that make Nile tilapia so suitable for fish farming are its general hardiness, easy breeding, rapid growth, efficient omnivorous food habits, and high quality flesh with good taste.

2.2 Major advantages

Nile tilapia can feed on a wide range of both natural and artificial foods. Although its major diet is phytoplankton, Nile tilapia can eat many other natural organisms including epiphytes, macrophytes, crustaceans and benthos. Such flexibility in feeding habits makes Nile tilapia easy to raise especially in green water of both polyculture and monoculture systems.

Nile tilapia is able to tolerate poor water quality and a wide range of environmental conditions in which few other species can exist. Other hardy species commonly used in aquaculture include air-breathing species such as catfish *Clarias* spp. and snakehead *Channa striata*. Nile tilapia has ability to tolerate extremely low dissolved oxygen (DO) concentration at the level of less than 1 mg/L in early morning. Nile tilapia can survive when DO drops briefly as low as 0.1 mg/L. However, they will die if the low DO persists for a long time period.

2.3 Major disadvantage

The major drawback in culture of tilapias including Nile tilapia is their early sexual maturity, which results in excessive recruitment in ponds. Tilapias reproduce when they are only a few months old, often well below the preferred market size. Uncontrolled spawning in production ponds often causes overpopulation resulting in competition for food, reduced growth, and lower yields of marketable size fish.

2.4 Methods for controlling excessive recruitment in pond culture

All-male Nile tilapia can be obtained by a number of methods - manual sorting by sex, sex reversal, and production of super males (YY). Manual sorting is labor intensive and requires experience and skills. The most popular and reliable method is to produce sex-reversed fry using male hormones. This method has been widely extended into fry production farms in Thailand and other parts of the region. The YY all-male Nile tilapia is produced through chromosome manipulation and is available only in some places.

Sometimes, carnivorous fish species can be used to control tilapia overpopulation as they prey on tilapia fry. Snakehead is probably the most popular and effective fish species used for this purpose. For example, stocking of snakehead at 250/ha can completely control tilapia recruitment in ponds stocked at 10-20,000 tilapia/ha. This method is very useful especially in the places where the supply of all-male Nile tilapia is not available.

If monosex tilapia and predator species are not available, the other choice is to manually remove fry from ponds. Starting three months after stocking, ponds can be partially harvested every month by seining or cast netting. The harvested tilapia can be either stocked in other ponds or sold as seed.

3. POND PREPARATION

3.1 Importance of pond preparation

Pond preparation is an essential practice to the success of fish culture. Good pond preparation can serve a number of purposes:

- Sterilize and improve soil quality of ponds;
- Induce production of natural foods;
- Increase tilapia survival;
- Maintain tilapia health;
- Ensure good growth and yield.

3.2 Procedures of pond preparation

Drain water from ponds completely and let ponds dry for 1-2 weeks until the bottom mud cracks. Upon drying, air and sunlight can enhance oxidation of reduced chemical compounds in pond bottom, and eradicate unwanted organisms, predators and micro-organisms.

Liming is an important procedure to increase alkalinity and pH in pond soil, maintain pH (7-8) in pond water, provide sufficient CO_2 for phytoplankton growth, and enhance good response to fertilization.

There are several liming materials available. The most commonly used liming materials are quick lime (CaO), slaked lime ($Ca(OH)_2$) and agricultural lime ($CaCO_3$). Agricultural lime is inexpensive and easy to use, but has lower neutralizing value. Slaked lime is quite reactive and thus should be handled with care. Quick lime is the most reactive and hence dangerous to use. It reacts vigorously with water to become slaked lime, the process that generates heat and raises pH rapidly.

The amount of lime applied to ponds depends on the nature of the soil and history of ponds. In general, newly dug ponds require greater amount of initial lime input than aged ponds; loamy soil needs less lime than clayey and acid soil.

The liming rates commonly used in Thailand are as followings:

- If ponds are newly dug, and have never been limed, one of these rates should be used:

Agricultural lime	1,000 kg/ha
Slaked lime	750 kg/ha
Quick lime	550 kg/ha

- If ponds are old and have been limed before, one of these rates is appropriate:

Agricultural lime	500 kg/ha
Slaked lime	375 kg/ha
Quick lime	275 kg/ha

These recommendations may vary and should be adapted to local conditions based on an acidity test of pond mud.

To enhance the lime reaction with pond soil, the pond bottom should be saturated with water prior to lime application. Lime should be spread evenly on the pond bottom and dike slopes. Application during windy weather should be avoided, otherwise lime will be lost when spreading.

One to two weeks after liming, ponds are ready to be filled with water. Inlet and overflow pipes should be covered with screen nets to prevent wild fish from being introduced. Some rocks, a piece of bamboo mat or a piece of iron wire can be put under the inlet pipe to protect the soil from being eroded there and the water from becoming too muddy during filling.

Fertilization using chemical fertilizers, manure or their combinations starts on the next day after filling and should continue on a weekly basis until water becomes green. Fertilization rates and application methods are included in sections four and six.

When Secchi disk visibility reaches about 30 cm, tilapia can be stocked. If the Secchi disk is not available, you may roughly test how fertile the pond water is by putting your arm in the water until it reaches your elbow, then look at your hand. If you can see your palm through the water, you need to add more fertilizers and test again before stocking tilapia.

4. STOCKING

4.1 Stocking density

Stocking density generally ranges from 0.5 to 3 fish/m^2 (5,000 to 30,000 fish/ha) in semi-intensive culture ponds, depending on the availability of resources such as fertilizers and feeds. Under similar pond conditions, fish size at harvest is usually bigger using lower stocking density. In nursing ponds where fry are reared to suitable size (about 50 g) for stocking in cages or grow-out ponds, the recommended stocking density is 10 fish/m^2.

4.2 Advanced nursing

Nile tilapia fry bought from hatcheries are normally less than 0.2 g. If such fry are stocked directly into ponds, survival is very poor. To increase the survival rate, hapas can be placed in ponds to nurse fry for a few weeks before releasing them to open pond water. A hapa is usually made of fine nylon net and is very similar to a rectangular or square shaped mosquito net, but upside down, with a bottom above the sediments and sides protruding out of the water.

Hapas of 5.4 m^2 (3.0 m x 1.8 m x 0.9 m) can be setup in grow-out ponds two weeks after the first fertilization; each hapa can accommodate 500 fry. The fry should be fed five times daily with the mixture of livestock concentrate for piglet, duck or chicken, and rice bran at 2:1 ratio; or fishmeal and rice bran at 1:2 ratio at the feeding rate of 10% body weight per day. The nursing period is normally two to three weeks, when fish reach 2-5 g size and can be released to open pond water. As hapas are often fouled by uneaten feed, fish feces and attached microbial growth, they should be cleaned with brash weekly.

5. FERTILIZERS AND FEEDS

5.1 Fertilizers

A large variety of animal manures is used as fertilizer in fish ponds. In general, the moisture, nitrogen (N) and phosphorus (P) contents of manures may vary considerably, depending on factors such as animal diet, purity and treatment of manures, and duration and conditions of storage. The moisture and nutrient contents listed in Table 1 are average values of the manures available in Thailand.

Table 1. Average moisture and nutrient contents of commonly used animal manures.

Animal manure	Moisture (%)	N (% dry matter basis)	P (% dry matter basis)
Chicken (bagged)	38	2.0	3.0
Duck (fresh)	82	3.7	1.7
Buffalo (fresh)	77	1.7	0.1
Dairy cattle (fresh)	86	0.5	0.1
Swine (fresh)	89	0.6	0.2
Sheep (fresh)	77	1.4	0.2

A number of chemical fertilizers with various N to P ratios are also used to fertilize fish ponds (Table 2).

Table 2. Approximate nutrient contents of commonly used chemical fertilizers.

Chemical fertilizers	N (%)	P (%)
Urea	45	0
Ammonium nitrate	35	0
Superphosphate	0	10
Triple superphosphate (TSP)	0	20
Diammonium phosphate (DAP)	18	24

Some guidelines for the most efficient fertilizing methods include:

- Manures should be distributed evenly across the entire pond once a week;
- N-fertilizers should be dissolved in water and spread evenly across the entire pond weekly;
- P-fertilizers should be soaked overnight and spread evenly across the entire pond weekly.

Methods used to calculate the amount of fertilizer to add differ based on the sources of fertilizer as follows:

- Animal manure when applied alone

Required manure (kg/pond/week, wet weight basis)

$$= \frac{[\text{Manure rate (kg/ha/week)}] \times [\text{pond surface area (m}^2)]}{(1\text{-\% moisture}) \times (10{,}000 \text{ m}^2)}$$

- Chemical fertilizers when applied alone

Required N-fertilizer (kg/pond/week)

$$= \frac{[\text{N rate (kg/ha/week)}] \times [\text{pond surface area (m}^2)]}{(\text{N\% in N-fertilizer}) \times (10{,}000 \text{ m}^2)}$$

Required P-fertilizer (kg/pond/week)

$$= \frac{[\text{P rate (kg/ha/week)}] \times [\text{pond surface area (m}^2)]}{(\text{P\% in P-fertilizer}) \times (10{,}000 \text{ m}^2)}$$

- Chemical fertilizers when applied with manure

Required N-fertilizer (kg/pond/week)

$$= \frac{[\text{N rate (kg/ha/week)} - (\text{manure rate (kg/ha/week)} \times (\text{N\% in manure})] \times [\text{pond surface area (m}^2)]}{(\text{N\% in N-fertilizer}) \times (10{,}000 \text{ m}^2)}$$

Required P-fertilizer (kg/pond/week)

$$= \frac{[\text{P rate (kg/ha/week)} - (\text{manure rate (kg/ha/week)} \times (\text{P\% in manure})] \times [\text{pond surface area (m}^2)]}{(\text{P\% in P-fertilizer}) \times (10{,}000 \text{ m}^2)}$$

Note: manure rate mentioned in above formula is on a dry-weight basis.

- Rates of addition for manures and chemical fertilizers (kg/ha/week) are developed in Section 6.

5.2 Feeds

A number of agricultural byproducts and commercial feeds can be supplemented to fish ponds to enhance fish growth and yields. The crude protein contents of commonly used agriculture byproducts and commercial pelleted feeds are listed in Table 3. Tilapia growth is generally more rapid when fish are provided feeds with higher protein content.

Table 3. Commonly used supplemental feeds and crude protein contents.

Feeds	Crude protein (%)
Rice bran	10.8
Wheat bran	10.9
Maize bran	8.5
Soybean cake meal	39.1
Pellet feeds	25-35

Feeding is normally performed manually. Feed should be given at least two times a day. Feeding frames for floating feeds and feeding trays for sinking feeds can be used to confine feed in a certain area and minimize loss. The places and times of feeding should be kept constant, and thus fish will become accustomed very quickly and consume feed efficiently.

6. FERTILIZATION STRATEGIES

Low cost fertilization strategies for small-scale farmers include the use of animal manure alone, chemical fertilizer alone, and the combination of animal manure and chemical fertilizers. While the nutrient input rates and ratios are the most important factors, these fertilization strategies provide a wide range of choices for small-scale farmers with various resources. The type of manures and chemical fertilizers is not of particular importance. Their cost and availability are essential factors in selecting which source to choose in a particular locale.

The CRSP fertilization strategies have been tested on-station in Northeast Thailand, and are practiced by many farmers in the region. The examples given below are results from experimental ponds, and yields are standardized based on two five-month production cycles per year.

6.1 Animal manure alone

Manure types and loading rates depend on availability. The maximum manure loading rate is 1,000 kg dry weight/ha/week, beyond which the water quality in ponds may become bad, causing mass mortality. Manure is generally applied on a weekly basis.

Chicken manure (CM) is one of the most commonly used animal manure. In the examples given in Table 4, chicken manure was applied weekly at loading rates ranging from 125 to 1,000 kg DW/ha/week. The results indicate that maximum net yield (3,500 kg/ha/yr) occurs using chicken manure at 1,000 kg/ha/wk, but this rate may cost considerably more than the yield of 3,000 kg/ha/yr using 500 kg/ha/wk of chicken manure.

Table 4. Examples of production of sex-reversed all-male Nile tilapia cultured at different chicken manure loading rates and stocking densities.

Strategy (kg/ha/week)	Stocking density (fish/m^2)	**Final size** (g)	Gross fish yield (kg/ha/year)	Net fish yield (kg/ha/year)
CM (125)	0.88	180	3,000	2,500
CM (250)	0.88	210	3,300	2,800
CM (500)	0.88	215	3,500	3,000
CM (1,000)	0.88	240	3,900	3,500
CM (500)	1.0	180	2,900	2,300
CM (500)	2.0	110	3,900	2,300
CM (500)	3.0	75	3,600	1,900

6.2 Chemical fertilizers alone

Urea and TSP are widely used chemical fertilizers in aquaculture. The optimized fertilization rate by CRSP methods is 28 kg N/ha/week and 7 kg P/ha/week, giving N:P ratio of 4:1. This fertilization rate is equivalent to 61 kg urea/ha/week and 35 kg TSP/ha/week (Table 5). Production for these inputs (6,000 vs. 3,500 kg/ha/yr) is considerably higher than using chicken manure alone, due to the better balance of nutrient inputs.

Table 5. Examples of production of sex-reversed all-male Nile tilapia cultured in ponds applied with chemical fertilizers alone.

Strategy (kg/ha/week)	Stocking density (fish/m^2)	Final Size (g)	Gross fish yield (kg/ha/year)	Net fish yield (kg/ha/year)
Urea(61) + TSP(35)	2.0	140	4,500	4,000
	2.7	150	7,100	6,400

6.3 Animal manure supplemented with chemical fertilizers

Animal manures have unbalanced N:P ratio, resulting in poor growth performance of Nile tilapia. To balance the N:P ratio, addition of chemical fertilizers is needed. In the examples given in Table 6, chicken manure was loaded to ponds at rates ranging from 25-225 kg (DM)/ha/week, and the amount of urea and TSP was adjusted to the amount of applied manure to provide 28 kg N/ha/week and 7 kg P/ha/week. This strategy produces the best overall yield (7,300 kg/ha/wk) and probably the most economically beneficial one.

Table 6. Examples of production of sex-reversed all-male Nile tilapia cultured in ponds fertilized at different chicken manure loading rates and supplemented with urea and TSP.

Strategy (kg/ha/week)	Stocking density (fish/m^2)	Final size (g)	Gross fish yield (kg/ha/year)	Net fish yield (kg/ha/year)
CM(225)+Urea(52)+TSP(1)	1.76	180	5,000	4,700
CM(175)+Urea(54)+TSP(9)	1.76	170	5,100	4,800
CM(125)+Urea(57)+TSP(16)	1.76	205	6,200	6,000
CM(75) +Urea(59)+TSP(24)	1.76	255	7,600	7,300
CM(25) +Urea(61)+TSP(31)	1.76	190	5,500	5,200

7. SUPPLEMENTAL FEEDING STRATEGIES

Size of Nile tilapia at harvest under fertilization alone usually averages 250 g in 5 months, and it may take as long as five more months to rear the fish to 500 g. In many countries, larger tilapia fetch much higher prices. To raise tilapia to large size, the addition of supplemental feeds to fertilized tilapia ponds is needed.

CRSP researchers have developed an efficient supplemental feeding system as followings:

- Fertilizing ponds at 61 kg urea and 35 kg TSP/ha/week throughout the culture cycle;
- Supplementing feeds at 50% of satiation feeding level starting when tilapia reach 100 g in size;
- Harvest tilapia when reaching 500-600 g in size.

The method to determine satiation feeding level is:

- Give feed to tilapia during 0800-1000 h and 1500-1700 h every Monday until tilapia stop feeding;
- Add all feed consumed in both sessions together, and the total feed amount is satiation feeding level;
- Feed tilapia 50% of the determined satiation feeding level from Tuesday through Sunday;
- Repeat the above process every Monday.

In the examples given in Table 7, Nile tilapia stocked in chemically fertilized ponds were fed commercial floating pelleted feed containing 30% crude protein, and the yields were standardized on two 5-month cycles. The yields were achieved in the ponds without aeration and water exchange.

Table 7. Examples of production of sex-reversed all-male Nile tilapia cultured in chemically fertilized ponds supplemented with commercial floating pelleted feed starting at different tilapia sizes.

Strategies	Stocking density (fish/m^2)	Final size (g)	Gross fish yield (kg/ha/year)	Net fish Yield (kg/ha/year)	Overall FCR
Start feeding at 50 g	3.0	592	19,600	19,000	1.14
Start feeding at 100 g	3.0	596	19,500	19,000	0.93
Start feeding at 150 g	3.0	530	15,200	14,700	0.93

8. CHOOSING APPROPRIATE STRATEGIES

When choosing fertilization and supplemental feeding strategies, cost and revenue are the most important factors in a particular locale. The selection of a suitable strategy should be based on simple economic evaluation according to local market prices of all inputs and outputs. Completing Table 8 will give you rough ideas whether a particular strategy is profitable, and help you make decisions on choosing an appropriate strategy.

Table 8. Estimating cost, revenue and return of a particular fertilization and supplemental feeding strategy.

	Items	**Unit (kg)**	**Price ($/kg)**	**Quantity (kg/crop)**	**Total ($/crop)**
COSTS	Fish fingerlings				
	Feed				
	N-fertilizer				
	P-fertilizer				
	Animal manure				
	Other costs				
	TOTAL COST				
REVENUE	Tilapia				
	Other fish				
	Gross revenue				
NET REVENUE = GROSS REVENUE – TOTAL COST					

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