RELATIVE CONTRIBUTION OF SUPPLEMENTAL FEED AND INORGANIC FERTILIZERS IN SEMI-INTENSIVE TILAPIA PRODUCTION

Eighth Work Plan, Kenya Research 3 (KR3)
Progress Report

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ABSTRACT

A 20-week experiment was conducted at Sagana Fish Farm, Kenya, to achieve the following: 1) characterize the productive capacity of ponds at this new CRSP research site; 2) evaluate the relative contributions of inorganic fertilizers and supplemental feeds to fish production; and 3) determine lowest-cost combinations of rice bran and inorganic fertilizer. Twelve 800-m^2 ponds were stocked with juvenile (32 g each) *Oreochromis niloticus* at 2 m^{-2} and *Clarias gariepinus* fingerlings (average weight 4.6 g) at 0.24 m^{-2}. Ponds contained about half sex-reversed and half mixed-sex tilapia, with an estimated ratio of approximately 75% males to 25% females at stocking. Four treatments were applied in triplicate as follows: 1) Urea and DAP to provide 16 kg N ha^{-1} wk^{-1} and 4 kg P ha^{-1} wk^{-1}; 2) Urea and DAP applied to give 8 kg N and 2 kg P ha^{-1} wk^{-1}, plus rice bran fed at 60 kg ha^{-1} d^{-1}; 3) Rice bran fed at 120 kg ha^{-1} d^{-1}; and 4) Rice bran as in Treatment 3 and fertilizer as in Treatment 2. Net fish yield averaged 1,127, 1,582, 1,607, and 2,098 kg ha^{-1} for Treatments 1 through 4, respectively. Fish in Treatments 2 through 4 were still growing rapidly at harvest time, but the growth rate of fish in Treatment 1 was beginning to decrease near the end of the experiment. Treatment 1 was the most cost-effective, but Treatments 1, 2, and 4 all resulted in fairly similar net profits. Input costs for Treatments 1 and 2 will be of interest to fish farmers, although it is possible that fish raised using only fertilizer at the rates in Treatment 1 may never reach market size at this stocking density, because of their reduced growth towards the end of the culture period and their resulting low final average weights, which were less than 100 g.

INTRODUCTION

Aquaculture development in Kenya has been hampered by a lack of complete feeds. The application of chemical fertilizers can enhance natural food production and indirectly provide protein to complement energy-rich rice bran. A 20-week experiment was conducted at Sagana Fish Farm, Kenya, to achieve the following:

1) Characterize the productive capacity of ponds at this new CRSP research site;
2) Evaluate the relative contributions of inorganic fertilizers and supplemental feeds to fish production; and
3) Determine lowest-cost combinations of rice bran and inorganic fertilizer.

This document is a report on progress to date, to be superseded by a final report when all data have been collected and analyzed.

METHODS AND MATERIALS

Lime was applied to all ponds at a rate of 5 t ha^{-1} prior to this experiment. The newest ponds received the lime treatment just prior to filling. Twelve 800-m^2 ponds were stocked with juvenile Nile tilapia *Oreochromis niloticus* (32 g each) at 2 m^{-2} and walking catfish fingerlings *Clarias gariepinus* (average weight 4.6 g) at 0.24 m^{-2}. Initially monosex tilapia were to be used for the study but the number of fingerlings available was insufficient to achieve the desired stocking density; mixed-sex fish were therefore added to complete the stocking. As a result, ponds contained about half sex-reversed and half mixed-sex fish, with an estimated ratio of approximately 75% males to 25% females at stocking.

Four treatments were applied in triplicate as follows:

1) Urea and DAP to provide 16 kg N ha^{-1} wk^{-1} and 4 kg P ha^{-1} wk^{-1};
2) Urea and DAP applied to give 8 kg N and 2 kg P ha^{-1} wk^{-1}, plus rice bran fed at 60 kg ha^{-1} d^{-1};
3) Rice bran fed at 120 kg ha^{-1} d^{-1}; and
4) Rice bran as in Treatment 3 and fertilizer as in Treatment 2.

Due to the relative newness of some ponds and a suspected high P adsorption capacity of newly exposed pond bottoms, the ponds were blocked according to the following criteria:

Block 1: New ponds, never before filled, that received lime just prior to filling.
Block 2: Ponds that had been limed and were in production for less than a month (These were drained and refilled prior to this experiment).

Block 3: Ponds that had been limed, filled, and in production (receiving feeds and fertilizers) for more than a month before the start of the present experiment.

Ponds were assigned randomly in a split block design (Table 1).

Dissolved oxygen, temperature, and pH were measured weekly in the morning and afternoon. Total alkalinity, chlorophyll *a*, Secchi disk visibility, and total ammonia nitrogen were measured every two weeks. Total N, mineral N, total P, and soluble reactive P were analyzed monthly. Samples for water chemistry were taken on Mondays, fertilizing was done on Tuesdays, and dissolved oxygen and temperature readings were done on Thursdays. Pond soils were sampled monthly for total N and P.

Ponds were sampled monthly to determine fish growth and drained completely after 20 weeks. Tilapia were separated by sex, counted, and weighed at draining. Tilapia reproduction was weighed and subsamples were counted. *Clarias* were also counted and weighed.

Table 1. Random pond assignment in split block design at Sagana Fish Farm, Kenya.

Treatment	Block 1	Block 2	Block 3
1	E05	D06	D05
2	E07	D07	E09
3	E04	D08	E03
4	E06	D04	E08

RESULTS

Although Treatments 1 through 3 were intended to be iso-nitrogenous, the rice bran contained less protein than expected. Total N and P inputs are summarized in Table 2. (The third batch of rice bran remains to be analyzed, so these numbers may vary slightly.)

Some of the ponds in Blocks 1 and 2 still had residual lime on their bottoms after draining; however, there were no significant differences in fish production between blocks. At harvest, the average weights of tilapia were 89, 106, 106, and 131 g and *Clarias* weights were 110, 217, 236, and 296 g for Treatments 1 through 4, respectively (Table 3). Male tilapia and *Clarias* showed significantly different average weights among treatments but differences among female tilapia were significant only for Treatments 1 and 4. Survival ranged from 67 to 88%; there were no significant differences by treatment. Males made up 65 to 71% of total tilapia numbers at draining, indicating that our estimate of 75% males at stocking was a bit high.

Fish began spawning during the first month of the experiment. However, due to the low number of females and the presence of *Clarias*, few fingerlings survived to harvest. Because it was somewhat difficult to distinguish initially stocked females from the larger fingerlings, some of the females may have been counted as fingerlings.

Net fish yield averaged 1,127, 1,582, 1,607, and 2,098 kg ha^{-1} for Treatments 1 through 4, respectively. Fish in Treatments 2 through 4 were still growing rapidly at harvest time, but the growth rate of fish in Treatment 1 was beginning to decrease near the end of the experiment (Figures 1 and 2).

Table 2. Preliminary data on nitrogen (N) and phosphorus (P) inputs for the experiment to evaluate the relative contributions of supplemental feeds and inorganic fertilizers in semi-intensive tilapia production.[a]

Treatment	Nitrogen Input		Total N (kg ha^{-1} wk^{-1})	Phosphorus Input		Total P (kg ha^{-1} wk^{-1})
	As Fertilizer	*As Feed*		*As Fertilizer*	*As Feed*	
1	16	0	16	4	0	4
2	8	6.5	14.5	2	3.64	5.64
3	0	13	13	0	7.28	7.28
4	8	13	21	2	7.28	9.28

[a] One of three rice bran lots has not yet been analyzed for N and P, so these figures may be slightly different after the final results are in.

Table 3. Final average fish weight, number of fingerlings, weight of tilapia reproduction, and average net fish yields by treatment. Numbers followed by the same letter are not significantly different at the 95% level (LSD).

Treatment	Tilapia					*Clarias*	Net Fish Yield (kg ha^{-1})
	Avg. Wt. Males (g)	*Avg. Wt. Females* (g)	*Avg. Wt. Mixed* (g)	*Number of Fingerlings*	*Weight of Reproduction* (kg)	*Avg. Wt.* (g)	
1	98 a	61 a	8 a	1,218 a	14.2 a	110 a	1,127 a
2	121 b	70 ab	106 b	837 a	12.5 a	217 b	1,582 ab
3	125 b	72 ab	106 b	1,230 a	15.7 a	236 b	1,607 ab
4	155 c	77 b	131 c	640 a	12.4 a	296	2,098 b

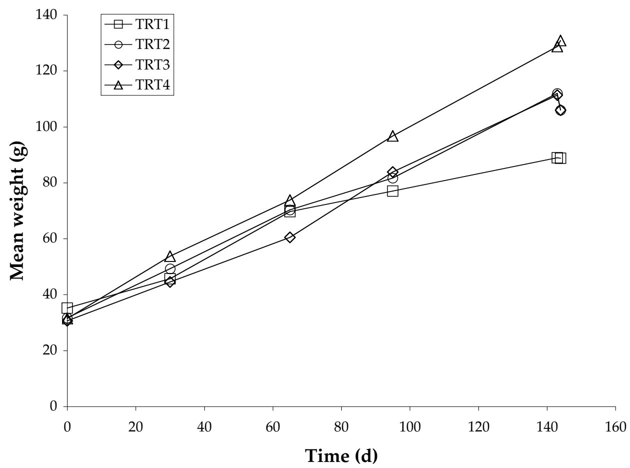

Figure 1. Tilapia growth for Treatments 1 through 4 during the 144-day experiment to evaluate the relative contributions of supplemental feed and inorganic fertilizer in semi-intensive tilapia production.

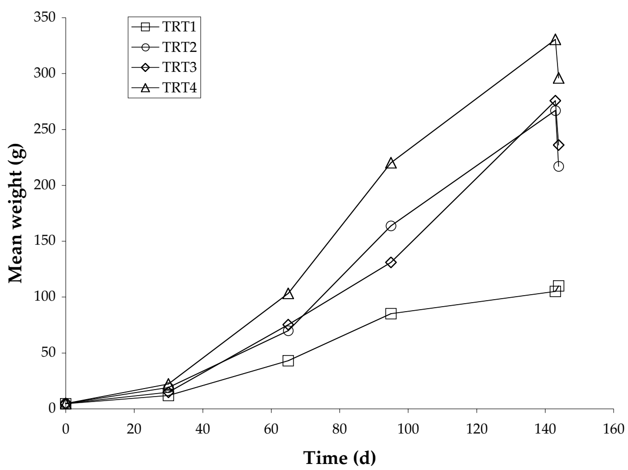

Figure 2. *Clarias* growth for Treatments 1 through 4.

Surface waters at Sagana have total alkalinity (TA) between 10 and 20 mg l^{-1} as $CaCO_3$. Total alkalinity in ponds receiving rice bran remained steady whereas TA for ponds receiving only chemical fertilizer declined after the first month (Figure 3).

Ponds in Treatment 1 had the highest average chlorophyll *a* concentrations. After December (month 2) the ponds in Treatment 3 (rice bran only) developed good algal blooms. Prior to December, however, they had little phytoplankton and dissolved oxygen levels were frequently less than 1 mg l^{-1} in the morning.

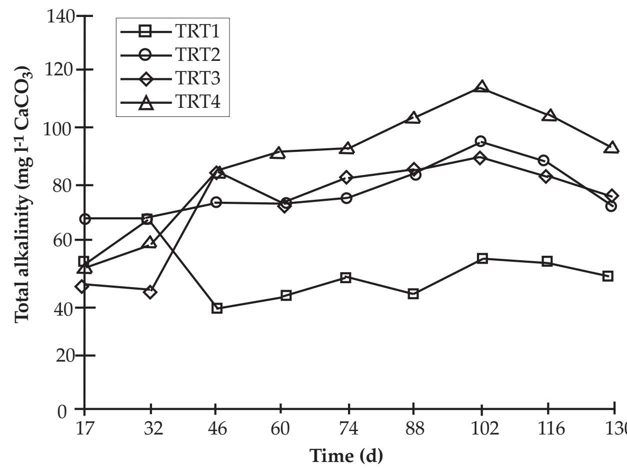

Figure 3. Average total alkalinity levels for ponds in Treatments 1 through 4 from Day 17 through Day 130 of the experiment.

Soluble reactive phosphorus concentrations were never higher than 0.05 mg l^{-1} in any pond. Total ammonia nitrogen never surpassed 0.5 mg l^{-1}. Nitrate and nitrite were low as well, except for a peak in nitrite (0.75 mg l^{-1} NO_2-N) on day 67 for pond E5 (Treatment 1). Ponds of all other treatments never surpassed 0.1 mg l^{-1} NO_2-N. "Black cotton" soils like the ones from which the Sagana ponds are built have notoriously high P adsorption rates. Assuming a clay content of 80% (ponds at Sagana are reported to have as much as 90% clay soils), a P adsorption capacity of 350 kg ha^{-1} was estimated using the formula proposed by Shrestha and Lin (1996). Only 80 kg P ha^{-1} was added to most ponds over the 20 weeks, so the P adsorption capacity was far from satisfied.

Nitrogen efficiency (kg net fish yield/kg N applied) averaged 3.52, 5.46, 6.18, and 5.0 for Treatments 1 through 4, respectively. The N:P ratio of the inputs was also lowest for Treatment 3.

Input costs for the different treatments are presented in Table 4. Treatment 1 was the most cost-effective, but Treatments 1, 2, and 4 resulted in fairly close net profits (Table 5). The higher production obtained in Treatment 4 more than compensated for the increased cost of adding fertilizer when compared with Treatment 3.

CONCLUSIONS

Cost of inputs for Treatments 1 and 2 will definitely be of interest to fish farmers. It is possible that fish raised using only fertilizer at the rates in Treatment 1 may never reach market size at this stocking density, as evidenced by their reduced growth towards the end of the experiment.

Table 4. Cost of inputs and labor per kg of fish harvested in Kenyan shillings (KSh). Numbers in parentheses denote costs if fingerlings harvested are subtracted from seed costs at 4 KSh each (60 KSh = US$1).

Treatment	Feed and Fertilizer	Labor	Fingerlings	Total Cost per kg Fish Produced
1	14.6	9.2	54.1 (17.5)	77.9 (41.3)
2	28.9	8.5	43.4 (23.2)	80.8 (60.6)
3	47.0	8.5	44.2 (14.0)	99.7 (69.5)
4	41.9	6.8	35.0 (22.5)	83.7 (71.2)

Table 5. Summary of costs and harvest revenues per pond, not counting fingerling costs, which were 200 KSh per pond, for all treatments. The price of adult fish is assumed to be 90 KSh per kg. No value is attributed to fingerlings harvested.

Treatment	Fertilizer (KSh)	Feed (KSh)	Input Labor (KSh)	Adults Harvested (kg)	Revenue (KSh)	Net Profit (KSh)
1	1,937	0	1,220	133	11,970	8,813
2	969	3,828	1,410	166	14,900	8,693
3	0	7,656	1,382	163	14,643	5,605
4	969	8,625	1,410	206	18,574	8,539

In order to further increase production over levels obtained using Treatment 2, applying additional fertilizer may be a better solution than increasing bran inputs. Diana et al. (1996) found that adding supplemental feed (floating pellets, 30% crude protein) after fish reached 150 g resulted in greater annual profit than either fertilization only or feeding right from the start. In this experiment, the bran was considered to function partly as feed and partly as organic fertilizer. At Rwasave Fish Station, Rwanda, an experiment was conducted in which fish were fed rice bran at 5 g fish^{-1} d^{-1} in ponds stocked at a density of 2 male tilapia m^{-2}. A mean net yield of 2,620 kg ha^{-1} and an apparent feed conversion of 7.6 were obtained after 192 days. No chemical fertilizers were applied, but small additions of chicken manure and grass were used as fertilizer (Verheust et al., 1992). The feed conversion ratios (FCRs) obtained in Treatments 3 and 4 of this experiment, in which rice bran was applied at 6 g tilapia^{-1} d^{-1}, are much higher (10.5 and 8 for Treatments 3 and 4, respectively) because the fish started out at a smaller size (32 g vs. 80 g in the Rwanda experiment) and they could not consume all the bran. Also, the ponds were harvested before market size was reached, thereby not allowing recovery from the overfeeding at the beginning of the experiment. A study that combined inorganic fertilization and feeding rice bran to tilapia (maximum application reached 46 kg ha^{-1} d$^{-1)}$ obtained a mean net yield of 1,160 kg ha^{-1} after 159 days (Perschbacher and Lochmann, 1995). This yield is somewhat less than the net yield in Treatment 2 of this experiment (1,582 kg ha^{-1}).

Bran prices vary in Kenya. Rice bran can be purchased for as little as 3 KSh kg^{-1}, but 6 KSh kg^{-1} is more common for farmers buying retail. At the price of 6 KSh kg^{-1}, rice bran should be applied sparingly and not as a fertilizer. Wheat bran is available in greater quantities than rice bran and retails for 5 to 7 KSh kg^{-1}. Wheat bran may present a better alternative to farmers and should be tested in future PD/A CRSP experiments.

Fingerling prices as they currently stand at Sagana constitute a major portion of total costs. The current price for fingerlings is 4 KSh each for both mixed-sex tilapia and *Clarias*. It appears that farmers in Central Province are aware that seed contributes so much to their costs and therefore choose to use mixed-sex fingerling tilapia (even when offered monosex for no additional cost), so that they do not have to re-purchase fingerlings. Fingerlings in Western and Nyanza Provinces sell for 1 KSh each for mixed-sex and 3 KSh apiece for all-male tilapia. Interest in using monosex fingerlings is greater in those provinces (M. Wafula, pers. comm.). The Sagana station management is considering reducing the price of fingerlings, possibly to as low as 0.5 KSh each for fry that have just been sex-reversed and to 2 KSh each for both mixed-sex and all-male tilapia of 4 to 5 grams in size. Larger tilapia (e.g., 20 g) and *Clarias* fingerlings would remain at 4 KSh each.

ANTICIPATED BENEFITS

Characterization of pond production at the Africa site using high nutrient input levels provides data for comparison with other CRSP sites. Reliable data on the value of low-cost supplemental feeds and comparative benefits of fertilization for semi-intensive tilapia production can also provide a basis for the development of more efficient production strategies in Kenya and similar areas of Africa.

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