Fish Yields and Economic Benefits of Tilapia/*Clarias* Polyculture in Fertilized Ponds Receiving Commercial Feeds or Pelleted Agricultural By-Products

Ninth Work Plan, Feeds and Fertilizers Research 2 (9FFR2)
Progress Report

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Abstract

There is a clear need to develop feed/fertilizer combinations that are appropriate for fish farming in Kenya and other parts of Africa. The strategy of using high-quality nutritionally complete feeds to produce high fish yields, frequently employed in developed countries, is often impossible or inappropriate in countries where high-quality feed ingredients are in short supply or are very expensive. However, the use of lower-quality pelleted feeds formulated specifically for tilapia, combined with fertilization regimes to increase the availability of natural food organisms, may be an economically appropriate approach for intensification of tilapia culture in Africa. This experiment is the second in a series designed to compare fish performance and economic benefits under different fertilization/feeding regimes—using low-cost, locally available materials—in earthen ponds. Water quality and fish growth sampling data were collected throughout the experiment, but data have not yet been analyzed. This report includes preliminary observations regarding the experiment. The experiment was conducted in twelve 800-m^2 earthen research ponds at Sagana Fish Farm, Kenya, between November 1999 and May 2000. Four replicates of each of three combinations of feed and fertilizer were tested. The treatments were Rice Bran (RB), Pig Finisher Pellets (PFP), and Test Diet Pellets (TDP). The experiment was concluded when fish reached market size, which occurred after 180 days. Water quality parameters were not significantly different ($P > 0.05$) among the three treatments except for total alkalinity, for which PFP ponds had a significantly higher ($P < 0.05$) mean value. Phytoplankton communities exhibited a strong seasonal succession, being dominated by green algae in the beginning and by blue-greens later in the cycle. Gross primary productivity ranged from 0.1 to 11.9 g C m^{-2} d^{-1} for all treatments. It took almost two months to develop phytoplankton blooms in the ponds, and fish growth was relatively slow at first. Fish receiving RB grew much slower than in similar treatments in previous trials. This was probably due to the lower-than-normal protein content of the bran. Average fish yield was greatest in ponds receiving PFP, followed by TDP, and finally by RB. Less than 50% of the fish in the RB treatment attained market size (300 g), whereas over 80% of the fish from the other two treatments were over 300 g. *Clarias* in all treatments attained market size of 600 g. If price varies by fish size, using PFP for supplemental feeding would be the best choice. RB treatment had significantly lower fish growth rate, net fish yield, and annual production compared to PFP and TDP ($P < 0.05$). However, there were no significant differences in survival rate and relative condition factor among the treatments. Relative profitability analysis using partial and enterprise budgets revealed that the PFP treatment was the best, followed by the RB treatment. Net returns were positive for all treatment regimes. However, RB had the lowest break-even price and the least investment cost.

Introduction

Commercial fish culture in developed countries generally achieves greatest profits when high-quality, nutritionally complete feeds are used to produce high fish yields. This strategy is often impossible or inappropriate in countries where high-quality feedstuffs are limited. In Africa, nutritionally complete diets for tilapia are very expensive. However, poultry diets and some purchased inputs, such as brans, can be used to intensify fish production in ponds. Disadvantages are that commercial poultry rations are not nutritionally balanced for fish, containing more digestible energy per unit of protein than recommended for fish, and brans are nutritionally deficient and often unconsumed by the fish due to small particle size. Pelletizing reduces feed losses, especially when multiple ingredients are included in the formulation. There is a clear need to develop feed/ fertilizer combinations that are appropriate for fish farming in Kenya (Ngugi and Wangila, 1996). Lower-quality pelleted feeds formulated specifically for tilapia, combined with fertilization regimes to increase the availability of natural food organisms, may be an economically appropriate approach for intensification of tilapia culture in Africa.

This report describes the pond production aspects of an experiment conducted at Sagana Fish Farm, Kenya, to compare fish performance and economic benefits of Nile tilapia (*Oreochromis niloticus*) and catfish (*Clarias gariepinus*) polyculture in fertilized ponds using three low-cost supplemental feeds. The supplemental feeds used were rice bran (RB), a commercially available pig finisher pellet (PFP), and a pelleted test diet (TDP) developed in collaboration with the same company that supplies the PFP.

Fertilization is often practiced to increase the abundance of natural food organisms in fish ponds receiving nutritionally deficient feeds. Assessment of the relative contribution of natural food organisms to fish growth in fed ponds would be a valuable contribution in the development of management practices involving nutritionally incomplete feeds. This assessment can be accomplished by analyzing the stable isotope ratios of nitrogen and carbon in the natural foods, feeds, and fish flesh; this is being undertaken by researchers at the University of Arkansas at Pine Bluff who will report separately on that work (see “Stable carbon and nitrogen isotope analysis of tilapia and *Clarias* fed commercial feeds or agricultural by-products,” 9FFR2A; p. 31 of this report).

METHODS AND MATERIALS

This experiment was originally planned to be conducted between July and November 1999, but its start was delayed by the late completion of the previous experiment (“Use of pond effluents for irrigation in an integrated crop/aquaculture system,” 9ER1), which had taken longer than expected due to slower-than-expected fish growth. Ponds were finally prepared and stocked for the experiment on 5 November 1999.

Twelve 800-m^2 research ponds at Sagana Fish Farm, Sagana, Kenya, were used for the experiment. Prior to filling, all ponds were limed at a rate of 20,000 kg ha^{-1} and fertilized as part of the test treatments, as described below. Each pond was stocked with 1,550 sex-reversed male tilapia (19,375 ha^{-1}; 90 g average weight) and 50 *Clarias*. Fish were fed twice daily at 2% body weight per day. Twenty-five tilapia were stocked in a cage in each pond and were not fed. These fish were part of a companion study in which they will be analyzed for C and N isotopes for comparison to fish in the open pond, which were fed.

Three treatments were applied in quadruplicate as follows:

- Rice Bran (RB) plus inorganic fertilization by applying diammonium phosphate (DAP) and urea at rates of 4 kg P ha^{-1} wk^{-1} and 16 kg N ha^{-1} wk^{-1};
- Pig Finisher Pellets (PFP), available locally, plus the fertilization regime of Treatment RB; and
- Test Diet Pellets (TDP) formulated to contain about 20% crude protein plus the fertilization regime of Treatment RB.

Rice bran had been tested as a supplemental feed in earlier work and so was used as the basis for comparison in this study. Pig finisher pellets were selected because they were less expensive than poultry pellets and because previous work indicated they were just as good as long as fertilizer was added on a regular basis. The feed in Treatment TDP contained no fish meal and was developed in consultation with the local fish feed manufacturer.

Fish were sampled by seining every two weeks to determine growth rates and adjust feeding rations. Thirty fish of each species were measured and weighed individually to obtain standard deviations. Fish and food/feed samples were collected at stocking, every 1.5 to 2 months during the experiment, and at harvest for isotope analysis. Gut contents of caged and free-swimming fish were collected at least twice to back up results of the fish tissue analyses.

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 nitrogen, mineral nitrogen, total phosphorus, and soluble reactive phosphorus were analyzed monthly. Samples for water chemistry were taken on Thursdays, fertilizing was done on Fridays, and dissolved oxygen and temperature readings were done on Mondays. All sampling and analysis was carried out according to standard CRSP sampling protocols.

Water lost through evaporation or seepage was replaced weekly. Otherwise no water was added to or allowed to flow through the ponds during the experiment.

The ponds were drained completely after 180 days, when the fish had reached market size. Tilapia were separated by sex, counted, and weighed. Tilapia reproduction was weighed and subsamples were counted. *Clarias* were counted and weighed.

RESULTS

Data for the pond production aspects of the experiment were collected throughout the experiment but have not yet been fully analyzed. Following are some preliminary observations concerning the experiment.

Water quality parameters were not significantly different ($P > 0.05$) among the three treatments except for total alkalinity, for which ponds fed PFP had a higher ($P < 0.05$) mean value than the other two treatments. The lowest dawn oxygen level (0.92 mg l^{-1}) was observed in the PFP treatment, while the highest afternoon level (9.9 mg l^{-1}) was recorded in the RB treatment. The phytoplankton community was dominated mainly by green algae in the beginning and later by blue-greens, exhibiting a strong seasonal succession. Gross primary productivity ranged from 0.1 to 11.9 g C m^{-2} d^{-1} for all treatments.

Fish growth was relatively slow at first, and it took almost two months for the ponds to develop phytoplankton blooms. Fish growth in the TDP ponds fell behind that in the PFP ponds after the nitrogen input rate was reduced in order to stay under 35 kg ha^{-1} wk^{-1} total N input as feed and fertilizer combined. However, TDP fish growth almost caught up with the PFP growth by the end of the experiment. The fish receiving RB grew much slower than fish under similar

Table 1. Harvest data for fish in ponds fed rice bran (RB), pig finisher pellets (PFP), and test diet pellets (TDP) during a 180-day experiment at Sagana Fish Farm, Sagana, Kenya. Numbers followed by different letters in the same column are significantly different at $P \leq 0.05$ using LSD multiple range test.

Feed Type	Gross Fish Yield (kg ha^{-1})	Average Tilapia Weight (g)	Tilapia > 300 g (%)	Average *Clarias* Weight (g)
Rice Bran (RB)	4,288[a]	218[a]	41[a]	603[a]
Pig Finisher Pellets (PFP)	6,156[b]	315[b]	82[b]	1,031[b]
Test Diet Pellets (TDP)	6,329[b]	326[b]	82[b]	1,147[c]

Table 2. Enterprise budget summary for an *Oreochromis niloticus*/*Clarias gariepinus* polyculture system using three supplemental feeds in fertilized ponds at Sagana Fish Farm, Sagana, Kenya.

Treatment	Income above Variable Costs (US$)	Net Returns to Land, Labor, and Management (US$)	Break-Even Price (Variable Costs) (US$)	Break-Even Price (Total Cost) (US$)
Rice Bran (RB)	2,168	1,742	0.67	0.76
Pig Finisher Pellets (PFP)	2,767	2,341	0.73	0.80
Test Diet Pellets (TDP)	1,992	1,566	0.84	0.91

treatment regimes in previous trials. This was probably due to the bran's lower-than-normal protein content. Average fish yield was greatest in ponds receiving PFP, followed by TDP and finally by RB (Table 1). Less than 50% of the fish in the RB treatment attained market size (300 g), whereas over 80% of the fish from the other two treatments were over 300 g. *Clarias* in all treatments attained market size of 600 g (Table 1). If price varies by fish size, using PFP for supplemental feeding would be the best choice.

All three feeds contained much lower protein levels than expected. The RB that previously tested at 11% crude protein (CP) contained only 5% CP when re-analyzed. The PFP was advertised as containing 14% CP but tested at only 10%. The TDP contained three types of oilseed meal, making up over 30% of the ingredients, but still tested at only 11% CP.

The RB treatment had significantly lower fish growth rate, net fish yield, and annual production compared to PFP and TDP ($P < 0.05$). However, there were no significant differences in survival rate and relative condition factor among the treatments.

Relative profitability analysis using partial and enterprise budgets revealed that the PFP treatment was the best, followed by RB (Table 2). The net returns were positive for all the nutrient regimes. However, RB had the lowest break-even price and the least investment cost.

ANTICIPATED BENEFITS

The development of cost-effective feeds in Africa may increase the profitability of fish farming in the region and stimulate commercial aquacultural enterprises. Collaboration with a local feed manufacturer can lead to a viable partnership with private enterprise to develop the most cost-effective tilapia feed for ponds in Kenya and the region. The production of natural food organisms in feed/fertilizer management practices is often highly variable across sites; the need to evaluate this more-intensive fish production practice under different environmental conditions may stimulate future intra-regional collaboration.

LITERATURE CITED

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