EFFECT OF STOCKING SIZE AND NUTRIENT INPUTS ON PRODUCTIVITY OF *OREOCHROMIS SHIRANUS* IN PONDS

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Final Report

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ABSTRACT

A study to investigate the effects of three different stocking sizes (5, 10, 20 g) and two isonitrogenous input regimes (maize bran × urea and napier grass × urea) on the production of *Oreochromis shiranus* was conducted between June and November 2000 at the Malawi National Aquaculture Center. Six treatments (three stocking sizes × two input regimes), each in triplicate, were used in the study. Inputs were applied to ponds stocked with fish at the three stocking sizes such that each input regime supplied 20 kg N ha^{-1} wk^{-1}. Fish were stocked at 2 fish m^{-2} and sampling (mean weight of 100 fish) was conducted biweekly. Water quality parameters (dissolved oxygen, pH, electrical conductivity, and Secchi disk visibility) were measured weekly, and total ammonia nitrogen and chlorophyll *a* were measured biweekly. The experiment was conducted over a period of 150 days.

The two isonitrogenous input regimes did not significantly affect fish net yield and growth rate. There were significant differences ($P < 0.05$) in fish growth rate and net yield between treatments. The highest fish growth rates and production (net yield) were achieved in ponds when fish were stocked at 5 g and either input regime was used, while ponds stocked with 20-g fingerlings and supplied with either napier grass × urea or maize bran × urea had the lowest net mean yield. There were significant differences ($P < 0.05$) in gross margins between treatments, with treatments where fish were stocked at 5 g and napier grass × urea were applied giving higher gross margins than the rest of the treatments. Mean fish survival rate was not significantly different between treatments. Results from this study suggest that stocking *Oreochromis shiranus* at 5 g results in higher fish production and gross margins compared to stocking larger fish. The results further show that under conditions where inorganic fertilization is used, substituting napier grass for maize bran increases profitability without affecting overall fish yield.

INTRODUCTION

Extensive tilapia culture using the indigenous *Oreochromis shiranus* is widely practiced by Malawian small-scale farmers, with initial stocking sizes and inputs varying widely in these systems. The major contributing factor to the stocking of fingerlings of mixed sizes is the lack of information on the optimal fingerling size for increased resource use efficiency and fish production. Various studies have demonstrated that stock manipulation procedures—e.g., intermittent stocking and stocking different sizes of fish—can significantly affect fish growth rate and net fish yield (McGinty, 1985; Knud-Hansen and Lin, 1996). Kaunda (1996) reported significant differences in net fish yield between different recruit-removal ratios. Stock manipulation during the production cycle is complicated and may be difficult to implement under small-scale conditions; therefore, simple stocking procedures that optimize fish yield are required. Simulation model results as well as practical experience show that high initial biomass and stocking rates reduce final yield in tilapia ponds (Lanhai, 1997). Jamu (1998), using a simulation model, also showed that final fish biomass and individual fish weights were very sensitive to changes in initial fish weights. Determination of the effects of initial fish size and inputs on fish yield is essential if stocking size and input strategies that optimize fish yields and profitability under small-scale fish farming conditions in Malawi are to be developed.

Table 1. Description of treatments used in the study.

Treatment	Description
1	• 5-g fingerlings at stocking • Maize bran applied at 3% of mean body weight per day (BWD) • Urea applied at a rate such that maize bran × urea constituted a total pond nitrogen input of 20 kg ha^{-1} wk^{-1}
2	• 10-g fingerlings at stocking • Maize bran applied at 3% BWD • Urea applied at a rate such that maize bran × urea constituted a total pond nitrogen input of 20 kg ha^{-1} wk^{-1}
3	• 20-g fingerlings • Maize bran applied at 3% BWD • Urea applied at a rate such that maize bran × urea constituted a total pond nitrogen input of 20 kg ha^{-1} wk^{-1}
4	• 5-g fingerlings • Napier grass applied at 350 kg ha^{-1} wk^{-1} (8.5 kg N ha^{-1} wk^{-1}) • Urea applied at 25 kg ha^{-1} wk^{-1} (11.5 kg N ha^{-1} wk^{-1})
5	• 10-g fingerlings • Napier grass applied at 350 kg ha^{-1} wk^{-1} (8.5 kg N ha^{-1} wk^{-1}) • Urea applied at 25 kg ha^{-1} wk^{-1} (11.5 kg N ha^{-1} wk^{-1})
6	• 20-g fingerlings • Napier grass applied at 350 kg ha^{-1} wk^{-1} (8.5 kg N ha^{-1} wk^{-1}) • Urea applied at 25 kg ha^{-1} wk^{-1} (11.5 kg N ha^{-1} wk^{-1})

The objectives of this study were to:

1) Determine the effects of different fish stocking sizes on *O. shiranus* productivity;
2) Evaluate the effect of two different isonitrogenous input regimes on *O. shiranus* productivity and profitability; and
3) Recommend, based on objective 2 above, stocking strategies that optimize fish productivity and input regimes on fish yield.

METHODS AND MATERIALS

Eighteen randomly selected 200-m^2 ponds located at the Malawi National Aquaculture Center in Zomba district were used for this study. Three fingerling sizes (5, 10, and 20 g) and two isonitrogenous input regimes (urea × maize bran and urea × napier [*Pennisetum purpureum*] grass) served as treatments in this study (Table 1). The total Kjeldahl nitrogen contents of the input materials used in these treatments are shown in Table 2. Each treatment was replicated three times. Fish were stocked at a rate of 2 fish m^{-2}. The experiment ran for 150 days (22 June to 24 November 2000).

Water was added weekly to replace losses due to evaporation and seepage. Water temperature was taken daily, while dissolved oxygen (DO), pH, electrical conductivity, and Secchi disk visibility were measured weekly. Total ammonia nitrogen and chlorophyll *a* were analyzed every fortnight using standard methods (APHA, 1989).

Ponds were harvested by seining followed by complete draining to remove any fish that remained in the pond sediments. Data were analyzed using Statistical Analysis Package for Scientists (SAS Institute, Inc., 1988). Specific fish growth rate (g d^{-1}) and extrapolated gross and net yield (kg ha^{-1} yr^{-1}) were calculated for each replicate pond. Gross margins (Upton, 1987) were calculated using input cost estimates for fingerlings, maize bran, urea fertilizer, and gross revenue from fish sales. Treatment means (± 1 standard deviation) were considered to be significantly different at an alpha level of 0.05. Means that were significantly different were separated using the Duncan's Multiple Range Test (Montgomery, 1997). Gross margins were calculated using the following formula (Upton, 1987):

$$GM = TR - (F_c + M_c + FG_c)$$

where

GM = gross margin (Malawian Kwacha ha^{-1} yr^{-1});
TR = total revenue (MK ha^{-1} yr^{-1}) from fish sales;
F_c = cost of urea fertilizer (MK ha^{-1} yr^{-1});
M_c = cost of maize bran (MK ha^{-1} yr^{-1}); and
FG_c = cost of fingerlings (MK ha^{-1} yr^{-1}).

The cost of labor required for napier grass application was not included in the analysis because farmers use their own and family labor for this operation.

RESULTS

Water Quality

There were no significant differences in water quality parameters between treatments ($P > 0.05$), and all water quality parameters except water temperature were within acceptable limits for *O. shiranus* (Wolfharth and Hulata, 1983). Pond water temperatures gradually increased over time from 16°C in June, July, and early August to 29°C for the remainder of the experimental period (Figure 1). The mean water temperature

Table 2. Total Kjeldahl nitrogen contents of the inputs used in this study.

Inputs	Nitrogen Content (% Dry Weight)
Maize Bran	2.22
Napier Grass (*Pennisetum purpureum*)	2.24
Urea	46.0

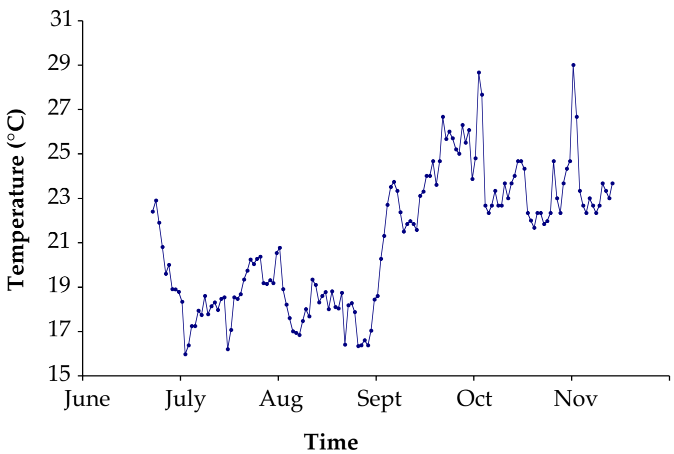

Figure 1. Mean monthly temperatures from 22 June to 24 November 2000.

during the experimental period was 22°C. Total ammonia nitrogen (TAN) concentrations were low and ranged from 0.01 to 1.12 mg l^{-1}. Conductivity increased over time, ranging from 29 to 83 mmho cm^{-1}, becoming highest towards the end of the experiment. Values of pH ranged from 5.3 to 8.1, increasing toward the end of the experiment. Early morning DO concentrations ranged from 3.1 to 9.6 mg l^{-1}. Chlorophyll *a* concentrations ranged from 10.4 to 42.6 µg l^{-1}. Secchi disk visibility decreased gradually with time, ranging from 17 to 39 cm.

Effect of Different Stocking Sizes on Production of *Oreochromis shiranus* in Ponds

Performance indicators for *O. shiranus* stocked at three different sizes and managed under two input regimes are presented in Table 3. There were significant differences in specific growth rates due to fingerling size at stocking ($P < 0.05$). Fish growth rate was highest in ponds stocked with 5-g fingerlings. There were significant differences in both gross and net yields due to fingerling size at stocking ($P < 0.05$). The highest net yield was obtained in ponds stocked with 5-g fingerlings, whereas those ponds stocked with 20-g fingerlings had the lowest net yield (Table 3).

Effect of Two Different Isonitrogenous Input Regimes on Production and Profitability of *Oreochromis shiranus*

Fish growth under the two input regimes is presented in Figure 2. There were no significant differences ($P > 0.05$) in specific fish growth rates and net fish yield between the two input regimes (Table 3). Fish growth was exponential up to the end of the experiment (Figure 2), suggesting that the pond carrying capacity was not reached in any of the treatments.

However, there were significant differences between the treatments in gross margins due to isonitrogenous input regimes ($P < 0.05$). Gross margin (MK ha^{-1} yr^{-1}) analysis showed that napier grass × urea gave higher returns than maize × urea at all stocking sizes. The highest gross margin was obtained in the treatment where fingerlings were stocked at 5 g and a combination of napier grass and urea was used (Table 3).

DISCUSSION

The mean weights of the fish in all treatments did not reach the desired size (> 60 g). This could be attributed mainly to low water temperatures that were experienced between the months of June and August. Specific growth rate was highest in ponds stocked with 5-g fingerlings, followed by those stocked with 10-g fingerlings and finally in ponds stocked with 20-g

Table 3. Performance indicators of *O. shiranus* in response to three different fish stocking sizes and two isonitrogenous input regimes. Treatments are as defined in Table 1 and the data are means of three replicates. Note: The price for fish was MK60.00 kg^{-1} (US\$0.83 kg^{-1}). Cost of labor was not included in determining gross margins. Means with similar superscript in the same row are not significantly different ($P > 0.05$).

Performance Measures	Treatments					
	1	2	3	4	5	6
STOCKING						
Total Weight (kg $pond^{-1}$)	2.1 ± 1.5	4.1 ± 1.2	7.9 ± 1.9	2.1 ± 1.4	3.9 ± 1.2	8.3 ± 0.8
Mean Weight (g $fish^{-1}$)	5.2 ± 0.9	10.3 ± 0.6	20.7 ± 1.8	5.1 ± 0.7	9.9 ± 1.2	20.1 ± 1.9
HARVESTING						
Total Weight (kg $pond^{-1}$)	14.6 ± 0.7	15.1 ± 0.6	15.9 ± 1.5	13.4 ± 0.5	14.2 ± 0.9	15.7 ± 1.1
Mean Weight (g $fish^{-1}$)	36.4 ± 1.5	37.8 ± 0.9	41.2 ± 0.6	34.8 ± 1.4	36.1 ± 1.6	40.1 ± 0.8
Total Weight Gain (kg $pond^{-1}$)	12.6 ± 1.5 ^{a}	11.1 ± 1.1 ^{a}	7.9 ± 1.2 ^{b}	11.4 ± 0.8 ^{a}	10.2 ± 2.6 ^{a}	7.7 ± 1.1 ^{b}
Mean Weight Gain (g $fish^{-1}$)	31.6 ± 1.6	27.8 ± 0.9	21.1 ± 0.6	29.8 ± 1.4	26 ± 1.6	20 ± 0.8
Specific Growth Rate (g $fish^{-1}$ d^{-1})	2.0 ± 0.9 ^{a}	1.3 ± 1.3 ^{b}	0.7 ± 0.6 ^{c}	1.9 ± 0.2 ^{a}	1.3 ± 0.9 ^{b}	0.7 ± 0.3 ^{c}
Net Yield (kg ha^{-1} yr^{-1})	1,508 ± 82 ^{a}	1,336 ± 66 ^{b}	965 ± 158 ^{c}	1,372 ± 56 ^{a}	1,238 ± 108 ^{b}	932 ± 128
Survival (%)	90 ± 0.8 ^{a}	88 ± 2.8 ^{a}	90 ± 5.2 ^{a}	89 ± 0.5 ^{a}	87 ± 5.8 ^{a}	88 ± 3.1 ^{a}
Gross Yield (kg ha^{-1} yr^{-1})	1,748 ± 82 ^{b}	1,816 ± 66 ^{a}	1,911 ± 182 ^{a}	1,613 ± 56 ^{b}	1,704 ± 103 ^{a}	1,892 ± 128 ^{a}
TOTAL COST (MK ha^{-1} yr^{-1})	59,712.44	63,284.82	78,545.12	53,492.11	57,492.00	63,492.00
GROSS MARGIN (MK ha^{-1} yr^{-1})	45,244 ± 3,549 $^{a, b}$	43,408 ± 3,641 ^{b}	38,384 ± 2,766 ^{c}	48,441 ± 2,553.2 ^{a}	47,677 ± 3,704 ^{a}	52,987 ± 1,907 ^{a}

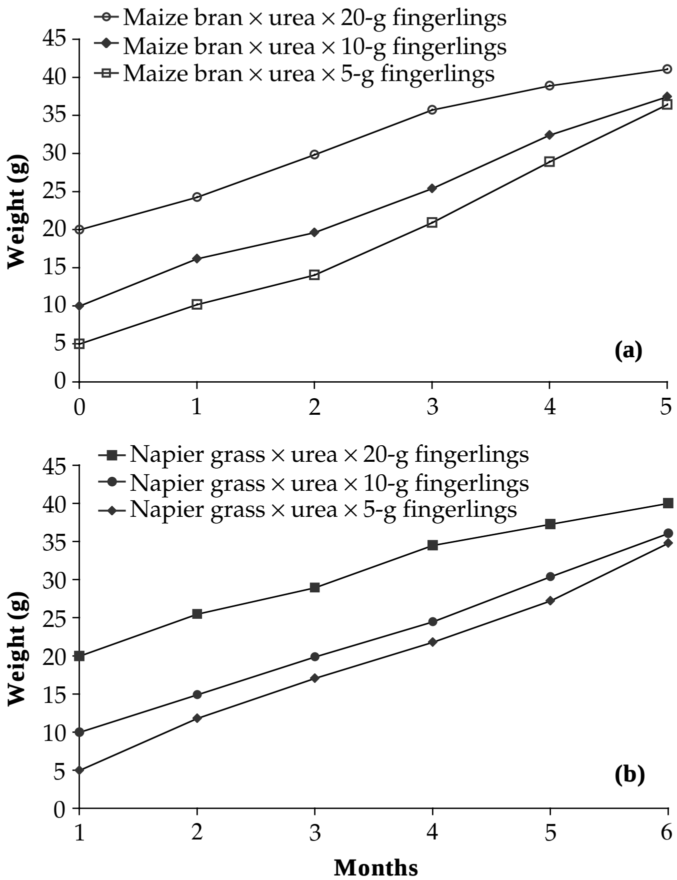

Figure 2. Effects of different stocking weights on growth of *O. shiranus* in ponds receiving two isonitrogenous (20 kg N ha^{-1} yr^{-1}) input regimes [maize bran × urea (a) and napier grass × urea (b)]. Fish were sampled from 22 June to 24 November 2000.

fingerlings. The specific growth rates for the 20-g fingerlings were similar to those obtained by Chikafumbwa (1996). Early breeding in tilapias has been reported to be related to the slowing of somatic growth (Lowe-McConnell, 1982). In this study, breeding was observed one month after stocking in ponds where 20-g fingerlings were stocked, and this could explain the low growth rates of fish in this treatment compared to treatments where fish were stocked at 5 and 10 g, respectively. High mean net yield of *O. shiranus* in treatments where 5-g fingerlings were used could be attributed to low initial biomass at stocking coupled with high growth rates that resulted in higher final net weight gain per unit time than in ponds stocked with 10-g and 20-g fingerlings, respectively. However, overall net yields were similar to those reported in other studies for similar systems (e.g., Chikafumbwa, 1996; Brummett, 2000).

There were no significant differences in fish growth rate and net yield between the two input regimes used in the study. Since the napier grass was applied as an organic fertilizer and maize bran was applied as a feed, it was expected that the maize bran × urea input regime would result in higher growth rates and fish production. Chikafumbwa et al. (1993), using delta carbon (δC) analysis, showed that *O. shiranus* derived most of its diet from detritus or phytoplankton. It is therefore likely that most of the maize bran (which small-scale farmers apply as a feed) contributed to the detrital food web, which was eventually targeted by the fish as food. Gross margin comparison favored the use of napier grass × urea as opposed to maize bran × urea. The cost of maize bran significantly contributed to high costs of growing *O. shiranus* in treatments where it was used. Although the labor required to cut and apply napier grass to ponds was not included in the gross margin analysis, available data (Chikafumbwa, 1996) show that 33 to 60 person-hours are required to cut and apply napier grass at a rate of 100 kg ha^{-1} d^{-1}. Because fish growth rate and net fish production and yield were similar between the two input regimes and gross margins were higher when napier grass and urea inputs were used, a combination of napier grass and urea inputs and an initial stocking size of 5 g could result in better fish production and profitability in low-input *O. shiranus* production systems where labor for cutting grass is cheap and readily available.

ANTICIPATED BENEFITS

The study was designed to evaluate the production and profitability of *O. shiranus* in experimental ponds where three different fingerling stocking sizes and two isonitrogenous pond input regimes were used, and it was designed to recommend a fingerling stocking size and input regime that result in better production and profitability. Results indicate that stocking fish at 5 g and using a combination of napier grass and urea as pond inputs gives the highest fish production and profitability. This management strategy will allow farmers to optimize fish production and profits while utilizing on-farm resources that would otherwise not be utilized on the farm. This study will also provide extensionists with information on stocking strategies and profitability of fertilized ponds in Malawi.

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