TRANSFER OF PRODUCTION TECHNOLOGY TO NEPAL FOR NILE TILAPIA, *OREOCHROMIS NILOTICUS*

Tenth Work Plan, Product Diversification Research 3 (10PDVR3)

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ABSTRACT

Given the need for the production of low-input animal protein in Nepal, the technical feasibility of tilapia production was assessed. Delayed feeding and fertilization-only treatments as well as stocking in cooler versus warmer temperature were compared between Genetically Improved Farmed Tilapia (GIFT) and Chitralada strains in southern Nepal conditions. While reasonably good growth and final weight at harvest were achieved, no significant differences were observed between delayed feeding and non-feeding treatments ($P > 0.05$). Similarly, no significant difference in growth rate and final weight at harvest was observed between GIFT and Chitralada strains ($P > 0.05$). Stocking during the month of August (29 to 35ºC) resulted in a faster growth rate with fish reaching market size (100 g) within three months. Fish stocked in December (16 to 25ºC) required over five months to reach the same size. Results of this study indicate that low-input (fertilization only) tilapia culture is feasible nine months of the year without need for overwintering using either GIFT or Chitralada strain. Moreover, stocking during the early spring (March or April), when morning temperature reaches 25ºC, would provide at least two crops (four-month cycle) annually.

INTRODUCTION

CRSP studies have made significant contributions to aquaculture of Nile tilapia, *Oreochromis niloticus*. These contributions include determination of optimal fertilization regimes for warm and cool weather conditions (Brown and Bolivar, 2001; Veverica et al., 2001), feeding rates and methods (Diana, 1997), production of monosex populations (Green and Teichert-Coddington, 1994; Phelps and Warrington, 2001), and polyculture of tilapia with other species (Syzper and Hopkins, 1997). The tilapia production industry, particularly in southeast Asia, has benefited a great deal from these and other innovations. Problem-based research studies at the Asian Institute of Technology (AIT) in Thailand have played a pivotal role in providing technical and research support that has facilitated the industry to expand in many different areas.

Additionally, low-input tilapia production has especially benefited resource-poor farmers in southeast Asia. Small-scale tilapia growers tend to consume their own fish, thus production increases have provided high-quality protein in household diets. Although fish is highly desirable in the Nepalese diet, annual consumption is only 1 kg per person (Edwards, 1998). Tilapia, lauded as a low-input aquaculture species, has the potential to provide cheap protein in a daily diet if culture technology is developed to benefit small-scale farmers. Unfortunately, tilapia production in Nepal suffers from lack of seed and production technology.

Lack of tilapia production in Nepal is also partly due to previous government policy to not introduce exotic species that might have negative impacts on local biodiversity and indigenous species. Although Nile tilapia was first transported to Nepal in 1985 and held in various government research stations for research and development purposes (Pullin, 1986), the origin of these strains is unclear, and further development work has not been carried out. There is an increasing need-driven interest among farmers to raise tilapia, evidenced by proliferation of imported seed from neighboring India across the open border. A number of farmers have brought tilapia seed to stock in their ponds and hapas. This uncontrolled and unchecked introduction of tilapia may have a negative impact on the livelihood of small-scale farmers.

The aim of this activity was to examine the growth rates of GIFT and Chitralada strains of Nile tilapia to be used as seed stock for introduction. The second goal was to test culture regimes using fertilization only and fertilization with delayed feeding on growth rates of Nile tilapia in southern Nepal. Moreover, temperature in this sub-tropical region drops below 19ºC during the winter in December and January, possibly preventing growth of tilapia. Since overwinter conditions affect culture systems for tilapia, stocking in winter (December) was compared against stocking during the summer (August) to determine the optimal stocking period to achieve marketable-size fish (100 g) within four to five months of culture.

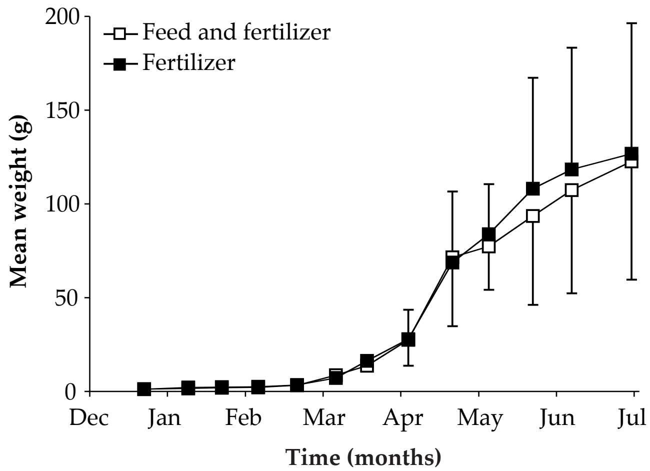

Figure 1. Changes in mean weight (with SD) over time for Nile tilapia (Chitralada strain) under culture with fertilizer only and fertilizer and feed as inputs.

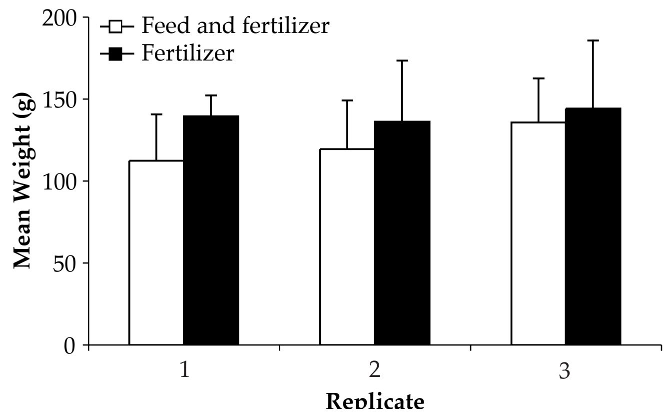

Figure 2. Mean (with SD) individual weight at harvest for replicates of Nile tilapia (Chatralada strain) under culture with fertilizer only or feed and fertilizer as inputs.

METHODS AND MATERIALS

Two consecutive trials were conducted during this study period: 1) Comparisons between fertilization and fertilization only and feeding, and 2) comparisons between GIFT (6th generation select) and Chitralada strains. The three-week-old Chitralada strain from AIT and the GIFT-select strain acquired from NAGRI-Department of Fisheries, Thailand, were air transported to Nepal. They were conditioned in hapas for six days prior to stocking. Two ponds of 200 m^2 each were partitioned into six equal compartments with bamboo frames and nylon screen nets. Spring water was pumped into the ponds after drying and liming. Ponds were fertilized with urea ammonium sulfate at a rate of 28 kg nitrogen ha^{-1} until green. This rate was then applied weekly to both ponds throughout the experiment. Mixed-sex fingerlings (30 d old) were stocked in respective ponds at 3 fish m^{-2}.

Experimental Trial 1 (Winter Stocking)

Six experimental units were stocked during the winter (14 December 2001) with 200 fish (Chitralada strain) each. Some mortality was observed on the second day of stocking. Dead fingerlings were removed and replaced with back-up stock. After 80 days of stocking, three of six randomly selected units were fed a prepared diet consisting of 67% rice bran and 33% fishmeal at 3% BWD. Every two weeks a sample of 50 fish was removed from each compartment to determine average weights.

Temperature was measured twice daily (at 0600 and 1600h), and other water quality parameters were monitored monthly. Dissolved oxygen, pH, ammonia, nitrite, and total hardness were measured at the National Agricultural Research Council (NARC) station laboratory following standard methods (APHA, 1985; Egna et al., 1987).

Fish were harvested after 190 d by seining and draining. Fish were individually counted and weighed. Final mean weight and survival rates were calculated. Total weight of recruitment was also determined. Significant differences in size at harvest among treatments were determined using a t-test ($\alpha = 0.05$).

Experimental Trial 2 (Summer Stocking)

Ponds were drained and dried following harvest of the first experimental trial. During the summer (8 August), the same six experimental units were divided into two groups of three and stocked with Chitralada strain fingerlings from Experiment 1 (n = 200) in one group and GIFT-select strain fingerlings from Experiment 1 in the second group. Only fertilization was applied at the rate described earlier. Every month a sample of 50 fish was removed from each compartment to determine average weights.

Fish were harvested after 190 d by seining and draining. Fish were individually counted and weighed. Total weight of recruitment was also measured for each unit. Final mean weight and survival rates were calculated. Significant differences in size at harvest among treatments were determined using a t-test ($\alpha = 0.05$).

RESULTS

Tilapia fry were sensitive to handling stress at low temperature. A large mortality during stocking was observed among the newly transported 3-week-old fry at day temperatures of 19 to 20ºC. The highest mortality (> 90%) was observed in GIFT fry, while Chitralada suffered only 30% mortality prior to stocking after transport. Because of this mortality and the lack of fry for stocking, Experiment 1 was conducted comparing fertilizer and feed treatments without including different strains of fish. Several fish stocked into the ponds were also found dead the morning after stocking and were replaced with healthy-appearing back-up stock. Stocking during December with low average morning temperatures (18.5 ± 0.7ºC) also resulted in no weight gain for the first two months of culture (Figure 1). It was not until the first week March, when morning water temperatures started to exceed 21ºC, that there were modest increases in individual fish weights (Figure 1). Highest monthly weight gain (from 14 to 71 g per fish) was observed between April and May sampling. There was a large variation in size throughout the culture period. After five months of culture, the fish had reached 129 g in size.

Feeding after 80 d of culture did not improve weight gain. There was a significant difference ($P > 0.05$) between the mean

Table 1. Size, growth, yield, and survival for tilapia at stocking and harvest for fish from each replicate in Experiment 1.

Parameter	Treatment and Replicate					
	Feed and Fertilizer			*Fertilizer Only*		
	1	2	3	1	2	3
Total Number Stocked	201	201	201	201	201	201
Weight at Stocking (g, mean±SE)	1.2±0.2	1.3±0.2	1.3±0.1	1.3±0.1	1.3±0.2	1.3±0.1
Number Harvested	78	68	79	53	54	60
Survival (%)	38.8	33.8	39.3	26.4	26.9	29.9
Mean Weight at Harvest (g per fish)	106.4	119.4	127.0	139.3	138.6	144.1
Daily Weight Gain (g)	0.45	0.51	0.54	0.59	0.59	0.61
Biomass of Fry Collected (kg)	0.7	0.2	1.2	0.1	2.5	1.2
Total Biomass at Harvest (kg)	8.4	8.3	11.2	7.5	9.0	9.8
Harvest (kg of stocked fish)	8.3	8.1	10.0	7.4	7.5	8.6
Net Yield (kg ha^{-1} yr^{-1})	2,325	2,265	2,819	2,054	2,083	2,418

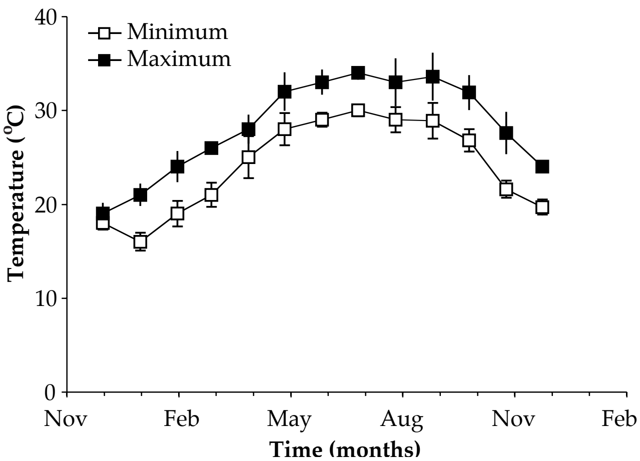

Figure 3. Average (with SD) monthly maximum (at 1600h) and minimum (at 0600h) temperatures (ºC).

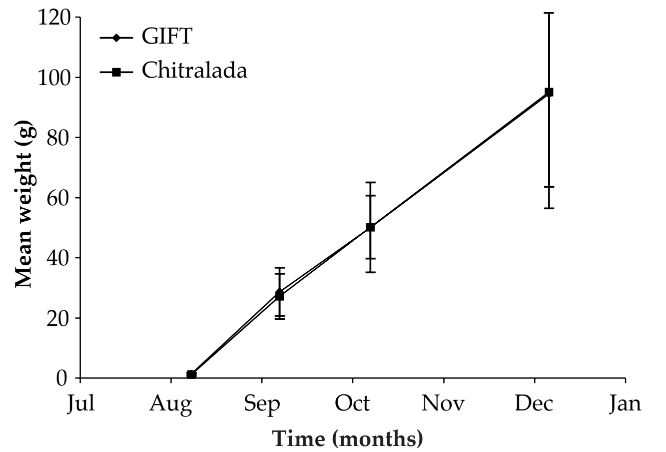

Figure 4. Changes in mean weight (with SD) over time for Nile tilapia of the GIFT-selected or Chitralada strains under culture with fertilizer.

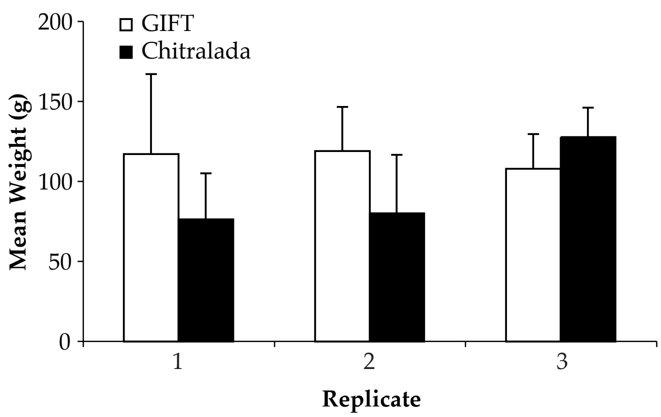

Figure 5. Mean (with SD) individual weight at harvest for replicates of Nile tilapia of the GIFT-selected or Chatralada strains under culture with fertilizer.

size of fish at harvest between treatments, and the group receiving feed and fertilizer (117 g) was significantly smaller ($P > 0.05$) than the group receiving only fertilizer (141 g) (Figure 2). Significant numbers of fry and fingerlings were harvested from these ponds, but there was no significant difference in fry production between treatments ($P > 0.05$).

Culture performance of fish in Experiment 1 was moderate. Overall, survival averaged 32.5%, and was significantly different between treatments ($P > 0.05$) (Table 1). Fish from fed and fertilized ponds had 37.3% survival, while fish from fertilized ponds had 27.7% survival. Daily growth averaged about 0.55 g d^{-1}, and was also significantly different between treatments ($P > 0.05$). In this case fish in the feed and fertilizer group averaged 0.50 g d^{-1}, while those in the fertilizer only group grew faster at 0.60 g d^{-1}. These differences in growth and survival among treatments resulted in no significant difference in net yield between treatments ($P > 0.05$), and net yield was moderate at 2,327 kg ha^{-1} yr^{-1}.

Water quality parameters were not out of the ordinary throughout Experiment 1. Temperature range varied from 14 to 37ºC over 12 months (Figure 3). However, the lowest monthly average temperature was not below 16 or above 34ºC. Pond water, from an on-station upwelling spring, responded well to fertilizer application and began to become green within two to three days. Low temperature appeared to be the largest cause of mortality during stocking and the cause of low growth of fish stocked in December.

In Experiment 2 with stocking during August when mean morning temperature was 29 ± 1.3 ºC, there was a steady

Table 2. Size, growth, yield, and survival for two strains of tilapia at stocking and harvest in Experiment 2.

Parameter	Treatment and Replicate					
	Chitralada			GIFT		
	1	2	3	1	2	3
Total Number Stocked	201	201	201	201	201	201
Weight at Stocking (g, mean±SE)	1.3±0.2	1.3±0.4	1.3 ±0.2	1.4±0.5	1.4±0.1	1.3±0.5
Number Harvested	95	180	108	112	128	140
Survival (%)	47.3	89.6	53.7	55.7	63.6	69.6
Mean Weight at Harvest (g per fish)	75.0	99.8	58.3	73.8	86.7	92.5
Daily Weight Gain (g)	0.56	0.74	0.43	0.55	0.64	0.69
Biomass of Fry Collected (kg)	2.6	3.7	1.6	4.9	2.1	2.9
Total Biomass at Harvest (kg)	9.7	21.7	7.9	13.2	13.2	15.8
Harvest (kg of stocked fish)	7.1	18.0	6.3	8.3	11.1	13.0
Net Yield (kg ha^{-1} yr^{-1})	1971	5192	1817	2394	3201	3750

but slow weight gain (Figure 4). Mean weight at harvest averaged 81 g and was not significantly different between strains ($P > 0.05$). Mean temperature remained high (> 22°C) for the first three months and then dropped to 20°C in December.

There was no significant difference in individual mean weight between GIFT-select and Chitralada strain raised under the same environmental conditions ($P > 0.05$) (Figure 5). Growth was rather slow at 0.60 g d^{-1}, which was not very different than in Experiment 1 under colder conditions. However, because of higher survival, the fish in Experiment 2 were grown at a higher average density.

Culture performance of fish in Experiment 2 was better than in Experiment 1. Overall survival averaged 63%, and was not significantly different between strains ($P > 0.05$) (Table 2). These differences in growth and survival among treatments resulted in no significant difference in net yield between treatments ($P > 0.05$), and net yield was higher than in Experiment 1 at 3,054 kg ha^{-1} yr^{-1}.

DISCUSSION

Tilapia can be grown in southern Nepal without the need for overwintering. Moreover, when stocked during the summer months, market size of fish might be attained within three months of stocking. Growth rates and final mean weights of both winter- and summer-stocked fish, however, were only about half of the values for previous trials in Thailand using similar fertilization and feeding regimes (Diana, 1997). A number of environmental factors may have contributed to lower growth rates besides temperature. For example, 3 fish m^{-2} may have been too high a stocking density, resulting in the pond exceeding carrying capacity quickly before fish reached a large size. However, the final stocking density (after mortality) was about 1 fish m^{-2} in Experiment 1 and 2 fish m^{-2} in Experiment 2. Seasonal and daily temperature fluctuations may have also contributed to the lower growth rates. Similar growth rates were observed by Dan (1999) in similar temperature regimes of northern Vietnam when high numbers of fish were stocked. Stocking during winter months resulted in low or no growth even when afternoon temperatures remained above 21°C. However, the overall growth rate in both experiments was not much different. One final factor that could have affected the growth rates was the use of mixed-sex fish, so that breeding occurred in the ponds. Breeding can detract energy from body growth and can also result in competition for food between fry and adult fish.

Previous studies demonstrated that by feeding later (80 d post-hatch) growth rate can be improved in Nile tilapia (Diana, 1997), although the magnitude of growth varies with the environment in which they are grown (Brown and Bolivar, 2001). The present study indicated no added advantage to feeding. Early stunting due to cooler temperatures may have contributed to this lack of higher growth in the fed group. Since growth in fed ponds would not improve unless food was limiting to fish growth prior to the supplemental feeding, the cold temperatures and fertilization regime may have provided enough food for growth to be sustained.

GIFT and Chitralada strains' growth have been compared at AIT and found no significant differences between the two strains (Yakupitiyage, 1998). Since the GIFT strain has been improved over six generations with intensive mass selection for growth, this particular improved strain had (prior to this study) not been tested against Chitralada strain. The lack of a measurable difference between these two strains indicates that the environment may play a greater role in determining growth rate than previously believed. Neither the GIFT nor the Chitralada strains appear particularly adapted to cooler conditions of southern Nepal. The Chitralada strain used in these experiments was very similar to the fish used in experiments in Thailand, except most experiments there were with sex-reversed fish.

The relatively high mortality rate of fish stocked in either season (37% during summer and 68% during winter) is difficult to explain. There may be strain differences for temperature tolerance, causing higher survival of the GIFT strain compared with the Chitralada strain. In both cases the fish fry were transported over 12 h from Bangkok to southern Nepal, which may have induced stress, causing delayed mortality after stocking. Given the easy access of the trial ponds, poaching also cannot be ruled out.

This set of two field trials in the conditions of southeastern Nepal clearly indicates limited potential for tilapia culture. Given that the tilapia fry survived the winter months, there is no need for overwintering and it is possible for local production of fish seed. It is also clear from the temperature profile that only three months of winter were detrimental to fish growth, leaving at least nine months to raise fish. Growth rates of 0.5 to 0.6 g d^{-1} would require about nine months to reach a final size around 130 to 150 g. Thus, our data indicate that one crop only could be grown per year with current growth rates.

Commercial fish feeds are unavailable in rural Nepal. The fact that we saw no increased growth by feeding affirms the importance of low-cost fertilization and negates the need for feeding. Technical feasibility of tilapia culture for the rural poor (for consumption and income generation) would benefit from an economic study based on low-cost and low-input conditions of southern Nepal.

ANTICIPATED BENEFITS

It is anticipated that NARC will work closely with the Nepal Agriculture Development Center (NADC) to use these introduced strains in farm trials. The NARC, which is charged with the distribution of new technology, will also develop a series of tilapia culture manuals to be distributed by agriculture extension agents based on this study and additional farm trials. A small hatchery has been built by the NARC to also accommodate incubation of tilapia embryos for seed production and distribution. Given the growing demand for cheap fish, the market is expected to continue to grow, which will also provide the incentive to grow low-cost and fast growing fish, which will benefit small- and mid-scale producers.

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