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Introducing tilapia (GIFT) with shrimp (*Penaeus monodon*) in brackishwater rice-shrimp system: impact on water quality and production

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Abstract

Mixed rearing of tilapia (GIFT; Genetically Improved Farmed Tilapia) with shrimp (*Penaeus monodon*) in brackishwater rice-shrimp system was assessed for its impact on dry season's shrimp production. The experiment was conducted in pre-selected farmer's field located at Paikgacha Upazila of Khulna district and designed with three different densities (treatment) of GIFT, *viz*, 0.3, 0.4 and 0.5/m^2 with a constant stocking density of shrimp at 3/m^2. Each treatment had three replications. There had a set of control treatment where GIFT was not stocked. Results of the experiment revealed that tilapia did not exert any significant effect ($p>0.05$) on the water quality variables, even on survival rate of shrimp ($p>0.05$) under farm level condition in rice-shrimp rotational system, but a density dependent negative effect ($P<0.05$) on the growth of shrimp led apparently lower production rate of shrimp. Though tilapia provided the major augment of total production ($p<0.05$) in the respective treatments than in monoculture of shrimp, but not that of the economic return. However, economic loss due to sudden shrimp crop failure might be partially minimized by the tilapia crop.

Keywords: Tilapia, shrimp, concurrent culture, impacts

Introduction

Shrimp in Bangladesh is one of the largest foreign currency earning sectors. Due to continuous disease outbreak, poor management such as overstocking, and environmental degradation, not only the production per unit area seemed to be very low but total crop failure also occurs frequently. In this situation, farmers are looking for the alternative culture system of either polyculture, crop rotation and/or crop diversification, which may provide an opportunity to develop a sustainable aquaculture system leading to best use of coastal shrimp farms in Bangladesh reducing the risk of unexpected shrimp crop loss.

In a polyculture setting, shrimp and tilapia may utilize different niches. In extensive culture, tilapia can filter feed on phytoplankton and zooplankton in the upper water column, while shrimp spend most of the time in the pond bottom grazing on bacterial films on the bottom substrate and on the detritus settling from above. Tilapia, as a filter feeder, can reduce excessive phytoplankton biomass in later stages of pond culture and recycle nutrients effectively (Stickney *et al.* 1979). A concomitant culture of Nile tilapia (*Oreochromis niloticus*) with shrimp has been reported (Perschbacher and Lorio 1993; Turker *et al.* 2003a, 2003b), but the red tilapia (*Oreochromis* spp.) has been found the best suite in shrimp ponds (Akiyama and Anggawati 1999).

Among the tilapias, GIFT (Genetically Improved Farmed Tilapia; improved strain of *Oreochromis niloticus*) is a most commonly cultured species in freshwater environment in Bangladesh. It could also be the best choice in brackishwater shrimp ponds as well due to its higher salinity tolerance ranging from 0 to 25 ppt (Hussain 2004). To date, most prawn and tilapia polyculture research has been conducted at fairly extensive stocking rates and under tropical or subtropical conditions in the world (Tidwell *et al.* 2000a, Yi and Fitzsimmons 2004). However, information regarding the concomitant culture of tilapia with shrimp at farm level coastal rice-shrimp system in Bangladesh is till scarce to nil. Therefore, the findings of the present study focused the rearing of tilapia and shrimp in a polyculture system and its effect on the culture environment, growth, survival and production at farm level conditions in the south-west Bangladesh.

Materials and methods

With the target of introducing GIFT (Genetically Improved Farmed Tilapia) and assessing its impact on growth, survival and production of shrimp (*Penaeus monodon*) as well as on the culture environment under field condition, an experiment was conducted during February to August, 2007 in 4 shrimp ghers, located at the Polder # 16/1 of Paikgacha, Khulna. Each gher was divided into three plots of almost identical size. The experiment was designed with three different stocking densities (T1=3000, T2= 4000 and T3= 5000 fingerling/ha) of GIFT along with a constant density of shrimp (30,000/ha). Each treatment had three replications. A set of control plots (T4) was also considered where GIFT was not stocked.

The plots were prepared followed by repairing dyke and liming the bottom soil with calcium oxide at a rate of 250 kg/ha. Tidal water was introduced up to a depth of 50 to 60 cm at the end of February. Phostoxin was applied @1tab/20 ton of water to kill the any unwanted animals introduced with tidal water. After three days, fertilizers were applied (Urea: 2.5 ppm, TSP: 3 ppm and MP: 0.6 ppm) and left over for the growth of primary producers. After seven days of fertilization (1^{st} week of March), hatchery produced post-larvae (ABW, 0.008 g) of *Penaeus monodon* were stocked in the plots according to the design. GIFT (ABW, 3.37 g) stocking was done after 30 days of shrimp stocking (beginning of April) when shrimp reached in a size of juvenile. All the plots were fertilized with Urea (0.5-1.25 ppm) and TSP (1.0-1.5 ppm) at fortnight intervals for the first 2 months, but Liming was done at a rate of 5-8 ppm with dolomite (Ca Ma $(CO_3)_2$) for the entire culture period. Shrimp were fed with commercial pellet feed, once a day, with 100%, 60%, 30% and 10% of the estimated shrimp biomass in the 1^{st}, 2^{nd}, 3^{rd}

and 4th week, respectively. However, the supplied feed varied from 2% to 3% of the standing shrimp biomass for the rest of the culture period.

During the entire culture period, gher water ecological parameters like, temperature, transparency, water depth, pH, dissolved oxygen, salinity and plankton population was monitored biweekly intervals following the standard methods of (APHA, 1985). After 90 days of rearing selective harvesting of shrimp was started using trap and continued up to 135 days. Harvesting of GIFT was done by dewatering of the plots at middle of August, 2007 just before rice plantation. Then growth, survival rate, FCR and production were estimated. Economic analysis was done considering all variable costs to the expenditure and respective shrimp and GIFT sales of the treatment to the gross return. ANOVA was done to observe the differences in growth, survival rate, production, FCR values and economic return among the different treatments.

Results and discussion

Water quality: Variations in water pH during the entire culture period have been presented in Fig 1. pH of water in all the treatments ranged within 7.2 to 8.6, indicating alkaline in condition. Alkaline water is more suitable, than neutral or acidic, for aquaculture . Acidic water restricts the growth of primary producer and also reduce feeding affinity of aquatic organisms (Boyd, 1990). However, water pH in the present trial was congenial for shrimp culture avoiding any unionized NH_3-N toxicity for prawn (New, 1995). Variation in pH during the entire culture period within the treatment was negligible and the difference among the treatments with increased stocking density of tilapia, even with the control one, was insignificant ($P>0.05$).

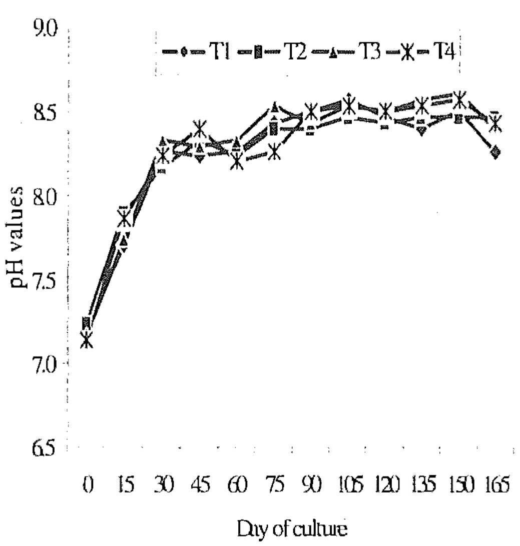


Fig. 1. Status in water pH under different treatments

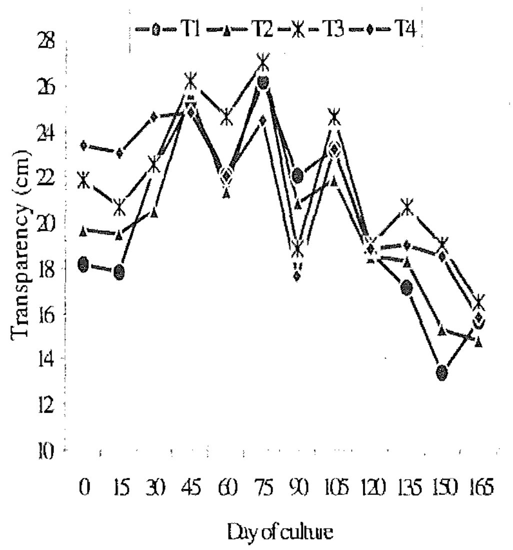
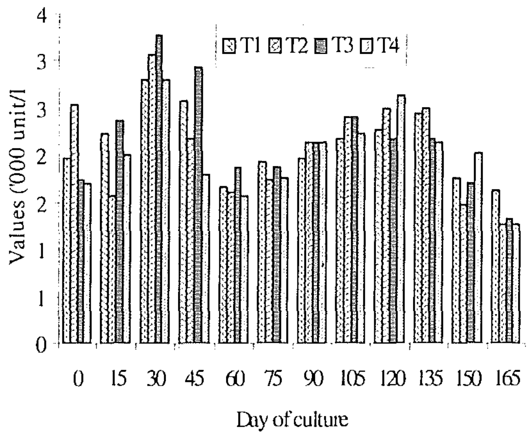


Fig. 2. Trend in transparency under different treatments

Water transparency in all the treatments was suitable from initial stage of culture to 60 days of culture (19.0 – 27.0 cm), afterwards it decreased in all the treatments with the increase in culture duration and reduced to minimum level (13-15 cm) at the end of culture (Fig. 2). Transparency in water might have been reduced due to heavy organic load (dense phytoplankton blooms) and/or due to excessive load in inorganic substances like, clay, silt, sand etc (Boyd and Tucker, 1989). At the same time, like that of transparency, the density of phytoplankton population also decreased with the progress in culture (Fig. 3). Values in dissolved oxygen showed minimum fluctuations among different sampling days (Fig. 4). Dissolved oxygen showed insignificant difference ($p>0.05$) among the treatments and always remained above sub-optimal levels (>4.0 mg/l), which was congenial for aquaculture, avoiding environmental stress for shrimp (Chanratchakool *et al.* 1995) and for GIFT (Hussain 2004).



ig. 3. Status in phytoplankton population in different treatments.

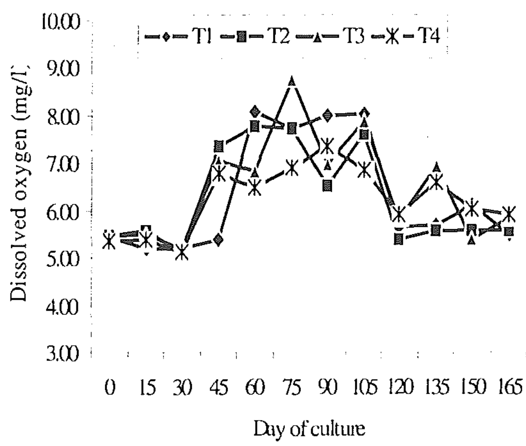


Fig. 4. Trend in dissolved oxygen under different treatments

Dense phytoplankton blooms with high photosynthetic rates can result in elevated pH levels (±10.0) in the afternoon, causing physical and physiological stress (Boyd and Tucker 1989) and even prawn mortality (Straus *et al.* 1991). Perschbacher and Lorio (1993), Turker *et al.* (2003a, 2003b) demonstrated that Nile tilapia, *Oreochromis niloticus*, has the ability of filter-feeding on phytoplankton and that subsequently reduces the pH level within the optimal ranges. Tian *et al.* (2001b) investigated water quality in a closed polyculture system containing Chinese penaeid shrimp with Taiwanese red tilapia and constricted tagelus. They found positive effect of polyculture on water pH control as well as controlling of planktonic blooms. Akiyama and Anggawati (1999) attributed positive effect to improving and stabilizing water quality, foraging and cleaning of the pond bottom, and having a probiotic type of effect in the pond environment by red tilapia. But our observation on water quality differs with the above mentioned authors. In this experiment, there was no significant difference in water pH, transparency even in plankton population among the treatments including control ones. The reasons behind these might be due to the variation of experimental condition and difference in culture practice. The above authors conducted experiments under closed condition with semi-intensive culture practice of shrimp, but our experiment was based on improved traditional system under farm level condition. In this system, regular intake of tidal waters in each lunar cycle a general phenomenon to maintain a minimum water depth, which was naturally loaded with silt and clay particles, reducing the water transparency, photosynthesis rate and blooming of plankton population as well as restricted pH elevation. However, other water quality parameters were similar (Table 1) in all the treatments and were within the acceptable ranges for Brackishwater aquaculture under farm level conditions in South-west Bangladesh (Wahab *et al.* 2001; Wahab *et al.* 2003; Islam *et al.* 2002; Islam *et al.* 2005).

Table 1. Mean±SD of water quality variables under different treatments in shrimp-GIFT concomitant culture

Variables	T1 (G+S)	T2 (G+S)	T3 (G+S)	T4 (only S)
Temperature (^{0}C)	30.54±3.015	30.39±3.070	30.89±3.079	30.74±3.104
Transparency (cm)	20.18±3.935	20.26±3.541	21.79±3.278	21.53±3.384
Depth (cm)	36.11±3.408	37.76±4.196	34.53±3.238	41.69±3.995
Dissolved oxygen (mg/l)	6.34±1.221	6.27±1.044	6.47±1.122	6.22±0.716
Alkalinity (mg/l)	153.78±17.855	156.39±19.098	155.44±21.175	156.06±21.277
NO_3-N (mg/l)	2.87±1.725	2.64±1.689	2.54±1.548	2.55±1.650
PO_4-P (mg/l)	2.64±1.280	2.80±1.295	2.79±1.269	2.64±1.059

** G=GIFT, S=Shrimp.

Growth and production: Growth and production performance of shrimp and GIFT under different treatments have been shown in Table 2. Final body weight of shrimp was insignificant (p>0.05) among the treatments, where GIFT was introduced with different densities. But it seemed significantly higher (p<0.05) in T4 (25.87 g), where GIFT was not stocked (control). Survival rate of shrimp lied between 34.41 to 36.44% in all the treatments and the difference among treatment was insignificant (p>0.05). The production of shrimp was 246.33, 235.98, 222.64 and 283.30 kg/ha in T1, T2, T3 and T4, respectively (Table 2). Though the shrimp production was apparently higher in T4, where no GIFT was stocked, it did not differ significantly (p>0.05) amomg the treatments. Despite of insignificant survival rate and production among the treatments, significantly higher weight gain of shrimp was obtained in the control treatment (T4), indicating some negative impact of GIFT on growth of shrimp. Observation of the present study differs with the observation of Akiyama and Anggawati (1999) and Tian *et* *al.* (2001a), who reported better growth, survival rate and production of shrimp in polyculture with tilapia than in monoculture of shrimp. This was probably due to the difference of culture practice. The authors conducted experiment under semi-intensive condition with higher stocking density of shrimp, where the deposition of organic matter was relatively higher than our condition, which supported available feed item for tilapia. But our experiment was based on improved traditional system with supplementation of commercial feed. GIFT as a fast feeder, required more feed with its body growth increment and would like to take the costly commercial feed faster than shrimp, and hence reduced shrimp growth. This observation was supported by Gonzales-Corre (1988), who observed negative effect of tilapia on shrimp growth and termed tilapia as a competitor of shrimp for food in polyculture settings.

Table 2. Production results of shrimp and GIFT under different treatments

Species	Particulars	T1 (G0.3/m^2+S)	T2 (G0.4/m^2+S)	T3 (G0.5/m^2+S)	T4 (only S)
Shrimp	Final weight (g)	23.03±0.51^{b}	21.68±1.08^{b}	21.55±0.96^{b}	25.87±0.45^{a}
	Survival rate (%)	35.57±6.19	36.07±7.20	34.41±4.98	36.44±5.96
	Production (kg/ha)	246.33±48.26	235.98±58.45	222.64±34.77	283.30±51.15
	FCR	1.93	2.15	2.27	1.84
GIFT	Final weight (g)	259.93±21.29	244.47±10.14	234.33±7.71	
	Survival rate (%)	53.02±6.28	49.42±6.42	42.20±4.16	
	Production (kg/ha)	413.79±59.71	484.40±77.48	495.32±63.84	
Total Production (kg/ha)		660.11±28.58^{abc}	720.38±48.47^{a}	717.95±30.66^{ab}	283.30±51.15^{d}

**Different letters in the superscript in same row indicate significant difference ($p<0.05$); G=GIFT, S=Shrimp.

Among the three tested stocking densities of GIFT, we observed relatively better growth of shrimp in the treatment where the stocking density of GIFT was lower (0.3/m^2). This indicated that lower stocking density of GIFT is more suitable in concomitant culture with shrimp under improved traditional culture in gher system. This observation was strongly supported by (Gonzales-Corre, 1988) who observed that the presence of Nile tilapia resulted in better growth and survival of shrimps at 0.4 tilapia/m^2, but poorer shrimp performance at a stocking density of 0.6 tilapia/m^2. Wang *et al.* (1998) also found that the optimum stocking density of Chinese shrimp and Taiwanese red tilapia was 6 shrimp/m^2 and 0.32 tilapia/m^2 (126.3 g in size), and shrimp growth and survival rate at all three stocking densities did not differ significantly among treatments. Tian *et al.* (2001a) reported that the best stocking rates were 7.2 shrimp/m^2, 0.08 tilapia/m^2 and 14 tagelus/m^2 in the polyculture of Chinese penaeid shrimp (*Penaeus chinensis*), Taiwanese red tilapia (*O. mossambicus* x *O. niloticus*) and constricted tagelus (*Sinonovacula constricta*).

Survival rate of GIFT was 53.02, 49.42 and 42.20%) in T1, T2 and T3, respectively, with insignificant difference ($p>0.05$) among the treatments (Table 2). Final body weight of GIFT was 259.93, 244.47 and 234.33 g in T1, T2 and T3, respectively and was also insignificant. Production of GIFT was 413.79, 484.40 and 495.32 kg/ha in T1, T2 and T3, respectively, which indicates a higher production rate from a higher stocking density. In this study, survival rate, weight gain and production of tilapia were density dependent. Akiyama and Anggawati (1999) reported density independent growth of Nile tilapia in polyculture with shrimp under semi-intensive culture condition.

Table 3. Economic return of shrimp and GIFT under different treatment

Particulars (Shrimp)	T1 (G0.3/m^2+S)	T2 (G0.4/m^2+S)	T3 (G0.5/m^2+S)	T4 (only S)
Production cost ('000 Tk./ha)	65.25±1.60	64.14±2.92	63.26±1.03	63.79±5.47
Gross return ('000 Tk./ha)	98.53±19.31	94.39±23.38	89.05±13.91	127.48±23.02
Net return ('000 Tk./ha)	33.28±17.88	30.25±20.47	25.79±12.90	63.69±21.93
BCR	1.51±0.26	1.46±0.29	1.41±0.19	2.00±0.34
Particulars (GIFT)				
Production cost ('000 Tk./ha)	5.93±0.44^{bc}	7.22±0.24^{ab}	8.32±0.44^{a}	
Gross return ('000 Tk./ha)	31.03±4.48	36.33±5.81	37.15±4.79	No GIFT
Net return ('000 Tk./ha)	25.10±4.23	29.11±5.79	28.83±4.38	
BCR	5.23±0.59	5.04±0.79	4.45±0.36	
Total for aquaculture				
Production cost ('000 Tk./ha)	71.18±13.68	71.35±30.80	71.58±0.78	63.79±5.47
Gross return ('000Tk./ha)	129.56±15.50	130.72±19.19	126.20±92.76	127.48±23.02
Net return ('000Tk./ha)	58.38±14.63	59.37±16.12	54.62±8.59	63.69±21.93
BCR	1.82±0.19	1.83±0.19	1.76±0.11	2.00±0.34

**Different letters in the superscript in same row indicated significant difference ($p<0.05$); G=GIFT, S=Shrimp.

The economic return of the present trial has been presented in Table 3. The net return from different treatments were similar ($p>0.05$), though it was apparently higher (63.69 '000Tk./ha) and BCR (2.00) from T4, where GIFT was not stocked. Similar to what has been reported by Akiyama and Anggawati (1999), GIFT concurrent culture of shrimp and GIFT augmented the total production through any undue reduction in shrimp and additional tilapia production. Despite of total lower production rate in T4 (Table 2), higher economic return (Table 3) was achieved, due to the quality of the product and higher market price, but at higher BCR. The lower size of shrimp in ponds with GIFT caused lower market price and economic return.

The results of the present trial focused that, though GIFT exerted a negative impact on the growth of shrimp, but not on survival and production. This might be due to feeding management and physico-biological conditions of gher that resulted in some degree of competition of GIFT with shrimp for food. Stocking of limited number of GIFT ($\approx 0.3/m^2$) might be helpful to increase the ecological condition of the farm by their omnivorous feeding nature. In concurrent culture, GIFT can reduce the production risk and economic losses to some extent, if the shrimp crop damaged due to any out-break of white spot viral disease. By changing the feeding schedule of GIFT (at day time) and shrimp (at night time) might be an option to reduce feed competition among GIFT and shrimp, because shrimp can eat well during the night time when Nile tilapia may not actively feed (Gonzales-Corre, 1988). Alternatively, tilapia could be confined in floating nets or cages to prevent them access to shrimp feed (Fitzsimmons, 2001). The present study has demonstrated that the tilapia-shrimp polyculture is technically feasible, and can be environmentally friendly and economically attractive with the appropriate feeding strategy. The use of cost effective diets and optimization of feeding inputs and schedules are therefore vital for sustainable shrimp-tilapia polyculture in coastal rice-shrimp system.

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