Demonstrating the Value of Tilapia and Sahar Production in Polyculture Ponds Using Government Farm and On-Farm Trials

Production System Design and Best Management Alternatives/Experiment/13BMA06UM

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Abstract

Carp polyculture is commonly practiced in Nepal but improving productivity of this aquaculture system is a major concern. Two trials were conducted to demonstrate the value of Nile tilapia and sahar in polyculture ponds. The first trial was conducted at the Fisheries Development Center, Bhairahawa, Nepal in nine earthen ponds of 200 m^2 for 240 days (9 August 2014 to 9 May 2015). The second trial was conducted in 12 farmer's earthen ponds (380–930 m^2) in Dayanagar-7, Rupandehi, Nepal for 165 days (10 July to 24 December 2015) to demonstrate the culture potential of sahar and tilapia to farmers. The first trial was conducted in a completely randomized design with three treatments in triplicate: a) Carps only or control (10,000 fish/ha) (T_1); b) Carps (10,000/ha) + tilapia (3000/ha) (T_2); and c) Carps (10,000/ha) + tilapia (3,000/ha) + sahar (1,000/ha) (T_3). Silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*) of mean stocking size 6.7, 3.8, 7.3, 3.1, 1.9 and 2.0 g, respectively were stocked in all ponds at the ratio of 3.5:1:2.5:0.5:1.5:1. The mean stocking size of Nile tilapia (*Oreochromis niloticus*) and sahar (*Tor putitora*) were 4.4 and 7.2 g, respectively. The ponds were fertilized weekly with urea and di-ammonium phosphate at 4 g N and 1 g P m^{-2} day^{-1}. Fish were fed once daily with locally made mass feed (1:1 rice bran and mustard oil cake; 20% CP) at 2% body weight. At harvest, the combined net fish yield was significantly higher in T_3 (3.93 ± 0.15 $t \cdot ha^{-1} \cdot yr^{-1}$) compared to T_1 (3.05 ± 0.26 $t \cdot ha^{-1} \cdot yr^{-1}$) whereas there was no significant difference between T_2 and T_3. There were no significant differences in survival and water quality among treatments. The gross profit margin was significantly higher in T_3 (2,357 ± 211 USD/ha) compared to T_1 (1,300 ± 316 USD/ha) without any significant difference between T_2 and T_3.

The farmer's field trial was composed of two treatments with six replicates each: a) Carps only or control (10,000 fish/ha); and, b) Carps (10,000/ha) + tilapia (3,000/ha) + sahar (1,000/ha). Common carp, silver carp, bighead carp, grass carp, rohu, and mrigal of mean stocking size 5.2, 5.3, 24.0, 16.2, 4.5 and 5.1 g, respectively were stocked in all ponds. The mean stocking size of Nile tilapia and sahar were 3.8 and 10.1 g, respectively. The ponds were fertilized weekly with urea and di-ammonium phosphate at 4 g N and 1 g P m^{-2} day^{-1}. Fish were fed once daily with commercial mass feed of 20% CP bought from local feed industry at 2% body weight. Other culture practices were similar to the first trial. At harvest, the combined net fish yield was significantly higher in polyculture of carps, tilapia, and sahar (5.6 ± 0.8 $t \cdot ha^{-1} \cdot yr^{-1}$) compared to only carps polyculture (4.2 ± 0.2 $t \cdot ha^{-1} \cdot yr^{-1}$). There were no significant differences in water quality parameters between treatments. The gross margin was significantly higher in polyculture of carps, tilapia, and sahar treatment (3,219 ± 367 USD/ha) compared to polyculture of only carps (1,800 ± 250 USD/ha). This study concludes that the carp-tilapia-sahar polyculture system is a better practice than

presently used carp polyculture system to enhance pond productivity and economically viable aquaculture.

INTRODUCTION

Aquaculture and fisheries in Nepal contributes about 0.93% to national GDP and 2.61% in agriculture GDP. It is one of the fastest growing economic and food producing sectors with growth rate of 8.4% per annum (Mishra 2015a). Pond aquaculture is the major aquaculture system practiced in ponds contributing more than 95% of total aquaculture, and 70% of this is contributed by exotic carps (Mishra 2015b). Carp polyculture practiced in Nepal is the mixed culture of common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), grass carp (*Ctenopharyngodon idella*), rohu (*Labeo rohita*), naini/mrigal (*Cirrhinus mrigala*) and bhakur/catla (*Catla catla*). Though all seven species are recommended in polyculture in certain ratios with a combined stocking density of 7,000–10,000 fish/ha, fingerlings of all species are rarely available when needed for stocking (Pandey 2002). Nile tilapia (*Oreochromis niloticus*) has been considered as another suitable aquaculture species in tropical and sub-tropical regions. However, it creates a significant challenge to control excessive recruitment of mixed-sex tilapia in the culture system (Shrestha et al. 2011), although such tests have been successfully done (Wang and Lu 2015). Tilapia can also be successfully cultured with freshwater prawn (Uddin et al. 2007, Tidwell et al. 2010). Sahar (*Tor putiotora*) is an indigenous fish species of Nepal which can be cultured successfully with carps and mixed-sex tilapia (Jaiswal 2010, Shrestha et.al 2011). Though an omnivorous species, sahar also shows predatory habits and has been proven as a simple mechanism to control tilapia requirement in ponds (Acharya et al. 2007, Paudel et al. 2007, Shrestha 1997a, Yadav et al. 2007). Sahar is the largest riverine sport fish of Nepal (Rai et al. 1997), which is economically important and exists in the rivers and streams of lower and mid hills (Negi 1994). The population of this species is declining across much of its native range due to habitat loss, over fishing, ecological alterations, and physical changes in natural environment such as damming (Desai 1994, Shrestha 1997, Baidya et al. 2006). This has led to efforts to conserve, manage, and propagate the species (Shrestha 1997a). Among several ways of conservation, incorporation of this species into the existing carp polyculture system is one.

Success in artificial propagation of Sahar in recent years has provided additional enthusiasm towards the development of this species for commercial cultivation (Raiet et al. 2006). Moreover, growth of sahar was found better in southern warmer climate (20–30°C water temperature) of Nepal as compared to the mid hill's cooler areas (Shrestha et al. 2004). Being an omnivore in nature it feeds on filamentous algae, insect larvae, small mollusks, and algal deposits on the rocks and has been determined to be predatory on small fishes (Shrestha 1997b, Acharya et al. 2007, Paudel et al. 2007, Yadav et al. 2007).

OBJECTIVES

- To increase pond productivity through species diversification;
- To demonstrate a carp-tilapia-sahar polyculture system for outreach potential by government fisheries development program;
- To demonstrate the culture potential of sahar and tilapia to farmers; and
- To develop partial enterprise budgets of costs and value of fish crops among treatments.

MATERIALS AND METHODS

The first trial was conducted at the Fisheries Development Center, Bhairahawa, Nepal in nine earthen ponds of 200 m^2 for 240 days (9 August 2014 to 9 May 2015). The trial was conducted in a completely randomized design with three treatments in triplicate: a) Carps only or control (10,000 fish/ha) (T_1); b) Carps (10,000/ha) + tilapia (3,000/ha) (T_2); and c) Carps (10,000/ha) + tilapia (3,000/ha) + sahar (1,000/ha) (T_3). Silver carp, bighead carp, common carp, grass carp, rohu, and mrigal of mean stocking size 6.7, 3.8, 7.3, 3.1, 1.9 and 2.0 g, respectively were stocked in all ponds at the ratio of

3.5:1:2.5:0.5:1.5:1. All the experimental ponds were completely drained and treated with hydrated lime ($Ca(OH)_2$) at the rate of 10.0 kg per 200 m^2 pond. The ponds were sun dried for two to three days and filled with ground water. Then, ponds were fertilized at 4 kg N and 1 kg P m^{-2} day^{-1} with di-ammonium phosphate (DAP) (18% N and 46% P_2O_5), urea (46% N) and farmyard manure (FYM). DAP and urea was used at 700 and 940 g, respectively and FYM at 60 kg for the 200 m^2 pond area. Fingerlings were stocked one week after pond fertilization.

Feeding was done with mass feed (20% CP) made from 1:1 mustard oil cake (28% CP): rice bran (12% CP) at 2% of total biomass per day in morning between 9:00 -10:00 am in feeding trays fixed in each pond. The quantity of feed was adjusted monthly based on fish sampling measurements. Fertilization with inorganic fertilizer was done at monthly after examining the Secchi disk measurements. Sampling of fish was done monthly from each pond starting from 30 days after stocking. During sampling about 10% of the stocked population of each species was weighed to calculate feed quantity for next month. For final harvest, all ponds were drained by pumping and all fish were harvested and weighed.

Partial budget analyses of all ponds were done using inputs and outputs. Inputs were calculated based on current market price of materials used in ponds. Similarly, outputs were calculated based on farm gate price of harvested fish. Average market price of carp fingerlings were USD 0.015, tilapia fingerlings was USD 0.03 and sahar fingerlings was USD 0.05 per piece. Similarly, market price of lime, urea, DAP and feed were 0.27, 0.30, 0.65 and 0.30 USD/kg, respectively. For output calculation farm gate price of silver and bighead carp was USD 1.5/kg, other carp species were USD 2.00/kg, Nile tilapia was USD 2.50/kg and sahar was USD 6.00/kg.

The second trial was conducted in 12 farmer's earthen ponds (380–930 m^2) in Dayanagar, Rupandehi, Nepal for 165 days (10 July to 24 December 2015) to demonstrate the culture potential of sahar and tilapia to farmers. The farmer's field trial was composed of two treatments with six replicates each: a) Carps only or control (10,000 fish/ha); and b) Carps (10,000/ha) + tilapia (3,000/ha) + sahar (1,000/ha). Common carp, silver carp, bighead carp, grass carp, rohu and mrigal of mean stocking size 5.2, 5.3, 24.0, 16.2, 4.5, and 5.1 g, respectively were stocked in all ponds at the ratio of 3.5:1:2.5:0.5:1.5:1. The mean stocking size of Nile tilapia and sahar were 3.8 and 10.1 g, respectively. The ponds were fertilized weekly with urea and di-ammonium phosphate at 4 g N and 1 g P m^{-2} day^{-1}. Fish were fed once daily with commercial mass feed of 20% CP bought from local feed industry at 2% body weight. Other culture practices and economic parameters were similar to the pond trial at the Fisheries Development Center.

The data were analyzed using one-way ANOVA in SPSS (V 16.0). For the significant difference in growth parameters and gross margin analysis among different treatments LSD was used to compare the means. For testing different growth, production and economic parameters of tilapia, T-test was used.

RESULTS

Experiment 1: Pond trials at the Fisheries Development Center. The overall production, food conversion ratio, and survival of fishes in different treatments are presented in Table 1 and Figure 1. There was no significant difference (p>0.05) in extrapolated GFY of carps, overall FCR, and overall survival rate in different treatments. Similarly, there was no significant difference (p>0.05) in extrapolated GFY of tilapia in T_2 and T_3. However, combined extrapolated GFY of all species including tilapia recruits in T_3 was significantly higher (p<0.05) compared to T_1 but not with T_2. Similarly, the extrapolated NFY of combined species excluding tilapia recruit in T_3 was significantly higher (p<0.05) than T_1.

Table 1: Production parameters (mean ± SE) in different treatments. Mean values in a row with the same superscript are not significantly different ($\alpha = 0.05$).

Parameters	Treatments		
	Carp (T_1)	Carp + Tilapia (T_2)	Carp + Tilapia + Sahar (T_3)
Extrapolated GFY ($t \cdot ha^{-1} \cdot year^{-1}$)			
Carps	3.13 ± 0.26^a	3.02 ± 0.15^a	3.33 ± 0.12^a
Tilapia	-	0.49 ± 0.05^a	0.45 ± 0.02^a
Sahar	-	-	0.14 ± 0.02
Combined	3.13 ± 0.26^b	3.51 ± 0.20^{ab}	3.93 ± 0.16^a
Including tilapia recruit		3.72 ± 0.22^a	4.04 ± 0.15^a
Extrapolated NFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	3.05 ± 0.26^b	3.57 ± 0.25^{ab}	3.93 ± 0.15^a
FCR	2.53 ± 0.24^a	2.62 ± 0.17^a	2.41 ± 0.11^a
Overall survival	81.2 ± 5.1^a	76.0 ± 3.0	80.5 ± 1.3^a

Growth and production parameters of different fish species are shown in Table 2. There were no significant differences in mean harvesting weight, total harvesting weight, mean daily weight gain (DWG), survival rate, extrapolated GFY, and extrapolated NFY of different carp species among treatments. However, total harvesting weight, extrapolated GFY and NFY of Nile tilapia in T_2 were significantly higher than in T_3.

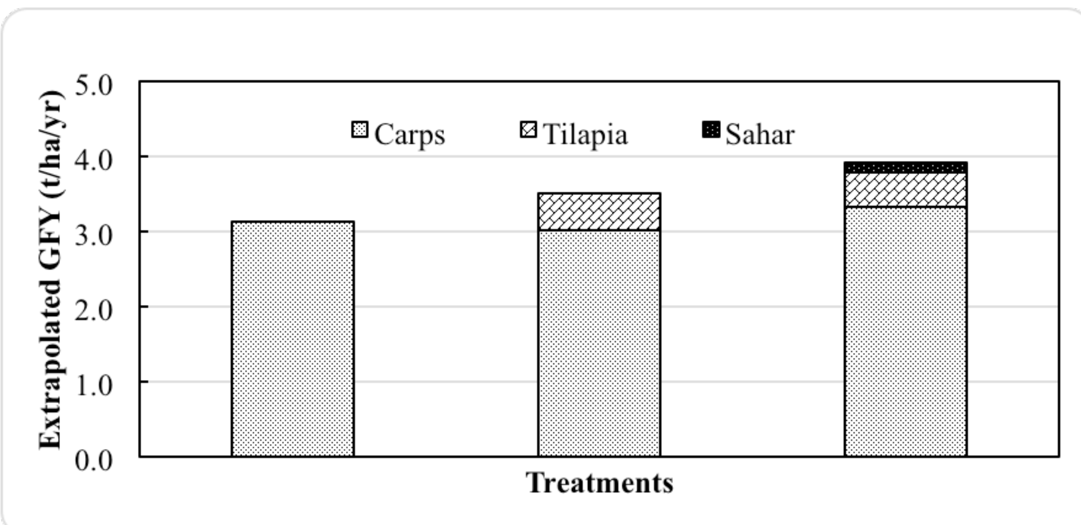

Figure 1: Extrapolated GFY of carps, tilapia and sahar in different treatments.

Table 2: Growth and production parameters (mean ±SE) in different treatments. Data based on 200 m^2 pond area. Mean values in a row with the same superscript are not significantly different ($\alpha = 0.05$).

Parameters	Treatment		
	Carp (T_1)	Carp+ Tilapia (T_2)	Carp + Tilapia + Sahar (T_3)
	Common Carp		
Mean Stocking Wt. (g)	7.26±0.09	7.22±0.06	7.27±0.06
Total Stocking Wt. (g)	363.1±4.45	361.47±3.23	363.93±3.12
Mean Harvesting Wt. (g)	285.74±46.77[a]	274.08±16.51[a]	299.91±41.33[a]
Total Harvesting Wt. (kg)	10.81±2.71[a]	10.80±1.66[a]	12.43±7.99[a]
Mean DWG ($g \cdot fish^{-1} \cdot day^{-1}$)	1.16±0.19[a]	1.11±0.07[a]	1.22±0.17[a]
Survival (%)	73.33±8.67[a]	78.00±7.02[a]	84.67±6.36[a]
Extrapolated GFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	0.82±0.21[a]	0.82±0.13[a]	0.95±0.06[a]
Extrapolated NFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	0.79±0.21[a]	0.79±0.13[a]	0.91±0.06[a]
	Grass Carp		
Mean Stocking Wt. (g)	3.05±0.06	3.13±0.00	3.18±0.12
Total Stocking Wt. (g)	30.46±0.55	31.38±0.04	31.87±1.15
Mean Harvesting Wt. (g)	204.76±32.67[a]	234.17±34.57[a]	212.88±42.84[a]
Total Harvesting Wt. (kg)	1.56±0.28[a]	1.46±0.24[a]	1.41±0.28[a]
Mean DWG ($g \cdot fish^{-1} \cdot day^{-1}$)	0.84±0.14[a]	0.96±0.14[a]	0.87±0.18[a]
Survival (%)	76.67±8.82[a]	63.33±8.82[a]	66.67±3.33[a]
Extrapolated GFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	0.12±0.02 [a]	0.11±0.01[a]	0.10±0.02[a]
Extrapolated NFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	0.12±0.02[a]	0.11±0.01[a]	0.10±0.02[a]
	Silver Carp		
Mean Stocking Wt. (g)	6.63±0.26	6.66±0.18	6.63±0.31
Total Stocking Wt. (g)	464.20±18.37	465.87±12.70	463.97±21.72
Mean Harvesting Wt. (g)	275.35±13.61[a]	278.07±8.79[a]	288.62±5.19[a]
Total Harvesting Wt. (kg)	16.91±0.95[a]	15.68±1.25[a]	17.39±0.46[a]
Mean DWG ($g \cdot fish^{-1} \cdot day^{-1}$)	1.12±0.06[a]	1.13±0.04[a]	1.17±0.02[a]
Survival (%)	88.57±8.61[a]	80.48±5.49[a]	86.19±3.72[a]
Extrapolated GFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	1.29±0.07[a]	1.19±0.10[a]	1.32±0.04[a]
Extrapolated NFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	1.25±0.07[a]	1.16±0.09[a]	1.29±0.03[a]
	Bighead Carp		
Mean Stocking Wt. (g)	3.86±0.01	4.07±0.02	3.61±0.15
Total Stocking Wt. (g)	77.2±0.26	81.47±0.39	72.1±2.92
Mean Harvesting Wt. (g)	322.97±33.78[a]	342.78±40.72[a]	284.13±6.65[a]

Parameters	Treatment		
	Carp (T_1)	Carp+ Tilapia (T_2)	Carp + Tilapia + Sahar (T_3)
Total Harvesting Wt. (kg)	5.79±0.49[a]	5.84±0.74[a]	5.21±0.22[a]
Mean DWG ($g \cdot fish^{-1} \cdot day^{-1}$)	1.33±0.14[a]	1.41±0.17[a]	1.17±0.03[a]
Survival (%)	90.00±2.89[a]	85.00±2.89[a]	91.67±1.67[a]
Extrapolated GFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	0.44±0.04[a]	0.44±0.06[a]	0.40±0.02[a]
Extrapolated NFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	0.43±0.04[a]	0.44±0.06[a]	0.39±0.02[a]
	Rohu		
Mean Stocking Wt. (g)	1.83±0.01	2.11±0.11	1.85±0.09
Total Stocking Wt. (g)	54.83±0.41	63.43±3.43	55.43±2.72
Mean Harvesting Wt. (g)	134.04±9.52[a]	136.36±35.26[a]	161.06±2.29[a]
Total Harvesting Wt. (kg)	3.24±0.38[a]	3.48±0.92[a]	4.19±0.20[a]
Mean DWG ($g \cdot fish^{-1} \cdot day^{-1}$)	0.55±0.04[a]	0.56±0.15[a]	0.66±0.01[a]
Survival (%)	80.00±3.85[a]	84.44±2.94[a]	86.67±3.85[a]
Extrapolated GFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	0.25±0.03[a]	0.26±0.07[a]	0.32±0.02[a]
Extrapolated NFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	0.24±0.03[a]	0.26±0.07[a]	0.31±0.02[a]
	Naini		
Mean Stocking Wt. (g)	1.93±0.15	2.16±0.14	2.01±0.09
Total Stocking Wt. (g)	38.6±2.92	43.27±2.83	40.10±1.70
Mean Harvesting Wt. (g)	206.67±5.91[a]	203.07±6.27[a]	200.62±15.19[a]
Total Harvesting Wt. (kg)	2.88±0.23[a]	2.42±0.81[a]	3.27±0.43[a]
Mean DWG ($g \cdot fish^{-1} \cdot day^{-1}$)	0.85±0.03[a]	0.84±0.03[a]	0.83±0.06[a]
Survival (%)	70.00±7.64[a]	60.00±20.82[a]	81.67±10.14[a]
Extrapolated GFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	0.22±0.02[a]	0.18±0.06[a]	0.25±0.03[a]
Extrapolated NFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	0.22±0.02[a]	0.18±0.06[a]	0.25±0.03[a]
	Nile tilapia		
Mean Stocking Wt. (g)	-	4.50±0.23	4.17±0.05
Total Stocking Wt. (g)	-	270.03±14.06	250.3±3.15
Mean Harvesting Wt. (g)	-	155.63±6.01[a]	156.17±5.41[a]
Total Harvesting Wt. (kg)	-	6.50±0.66[a]	5.94±0.29[b]
Mean DWG ($g \cdot fish^{-1} \cdot day^{-1}$)	-	0.63±0.02[a]	0.63±0.02[a]
Survival (%)	-	69.44±5.47[a]	63.33±0.96[a]
Extrapolated GFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	-	0.65±0.09[a]	0.56±0.01[b]
Extrapolated NFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	-	0.63±0.09[a]	0.54±0.01[b]

Parameters	Treatment		
	Carp (T_1)	Carp+ Tilapia (T_2)	Carp + Tilapia + Sahar (T_3)
	Sahar		
Mean Stocking Wt. (g)	-	-	7.22±0.32
Total Stocking Wt. (g)	-	-	144.57±6.37
Mean Harvesting Wt. (g)	-	-	104.61±9.49
Total Harvesting Wt. (kg)	-	-	1.81±0.20
Mean DWG ($g \cdot fish^{-1} \cdot day^{-1}$)	-	-	0.41±0.04
Survival (%)	-	-	86.67±6.01
Extrapolated GFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	-	-	0.14±0.02
Extrapolated NFY ($t \cdot ha^{-1} \cdot yr^{-1}$)	-	-	0.13±0.02

Total number and weight of small tilapia recruits in T_2 were higher than in T_3 while there were no medium tilapia recruit in T_3 (Table 3). However, total number and weight of large sized tilapia recruits were higher in T_3 compared to T_2.

Table 3: Tilapia recruitment in different treatments (weight in mean ± SE). Data based on 200 m^2 pond area.

Recruit Size	Parameters	Treatment	
		Carp+ Tilapia (T_2)	Carp+ Tilapia+ Sahar (T_3)
Small (2-3 cm)	Total count (no.)	2829	795
	Total wt. (kg)	4705	1205
	Mean wt. (g)	1.66±0.06	1.53±0.06
Medium (5-6 cm)	Total count (no.)	32	
	Total wt. (kg)	455	
	Mean wt. (g)	14.02±0.43	
Large (12-15 cm)	Total count (no.)	120	149
	Total wt. (kg)	3035	3290
	Mean wt. (g)	15.25±0.60	21.79±1.32

Water quality parameters of different treatments are shown in Table 4. There was no significant difference in average temperature or DO among treatments during the experimental period however, transparency was significantly higher in T_2 than in T_1 and T_3. Temperature decreased from September to January and later increased from January to May.

Table 4: Water quality parameters (mean ±SE with range in parentheses) of different treatments. Mean values in a row with same superscript are not significantly different (α = 0.05).

	Treatments		
Parameters	T_1	T_2	T_3
Temperature	23.03±0.40[a]	23.3±0.20[a]	23.48±0.03[a]
	(11.3-32.7)	(12.6-32.5)	(13.4-32.6)
pH	6.7	6.3	6.5
	(5.7-8.9)	(5.1-9.1)	(5.4-8.5)
DO	4.99±0.82[a]	5.70±0.04[a]	5.37±0.34[a]
	(2.1-7.2)	(4.9-6.6)	(4.0-6.5)
Transparency	33.38±0.31[a]	35.29±0.49[b]	32.14±0.59[a]
	(24-55)	(25-51)	(24-50)

The variable costs in all treatments consisted of seed, feed, feeding tray, lime, urea, DAP and FYM. Variable costs and outputs of different treatments are shown in Table 5. Cost of feed and total variable cost in T_1 was significantly lower than T_2 and T_3 ($p<0.05$). There was no significant difference in all other variable costs among different treatments ($p>0.05$). There was no significant difference in outputs from all fishes among different treatments ($p>0.05$). The gross profit margin was significantly higher in T_3 compared to T_1 without any significant difference between T_2 and T_3 (Table 5).

Table 5: Economic analysis (in USD) for each treatment. Data based on 200 m^2 pond area. Mean values in a row with the same superscript are not significantly different (α = 0.05).

	Treatments		
Variables	T_1	T_2	T_3
Seed	3.00	4.80	5.80
Feed	29.98±0.21[b]	36.67±2.12[a]	37.24±0.58[a]
Lime	2.43	2.43	2.43
Urea	1.57	1.57	1.57
DAP	0.97	0.97	0.97.
Feeding Tray	1.00	1.00	1.00
FYM	5.55	5.55	5.55
Total input	45.01±0.21[b]	53.50±2.12[a]	55.07±0.58[a]
Total output	71.00±6.53[b]	84.87±5.76[ab]	102.22±4.80[a]
Gross margin	24.90±6.32[b]	31.37±3.54[ab]	47.15±4.22[a]
Gross margin/ha	1299.50±315.90 [b]	1568.65±177.00 [ab]	2357.4±210.8 [a]

Experiment 2: Pond trials in farmer's ponds. The addition of Nile tilapia and sahar into carp polyculture ponds did not affect the growth and production of all carp species (Table 6). All carp species showed better performance in all treatments with a daily weight gain of 0.8 to 3.0 g. The daily weight gain of Nile tilapia and sahar were 0.7 and 0.03 g, respectively.

Gross and net fish yield of common carp, silver carp and mrigal were significantly higher in polyculture of carps, tilapia and sahar compared to polyculture of only carps ($P < 0.05$). There were no significant differences in gross and net fish yield of bighead carp, grass carp and rohu between the treatments.

The combined gross and net fish yield was significantly higher in polyculture of carps, tilapia and sahar compared to polyculture of only carps ($p < 0.05$, Table 7). There was no significant difference in overall food conversion ratio between the treatments. There was also no significant difference in water quality parameters between two treatments (Table 8). Economic analysis showed that the gross margin was significantly higher in polyculture of carps, tilapia and sahar compared to polyculture of only carps ($p < 0.05$, Table 9).

Table 6. Individual performance of carps, Nile tilapia, and sahar (mean ± SE) in each treatment. Data based on 500 m^2 pond area. Mean values with different superscripts in the same row were significantly different ($p < 0.05$).

Parameters	Treatments Carp+tilapia+sahar	Treatments Carps only
Common carp		
Stock number	125	125
Total stock weight (kg)	0.6 ± 0.0^{a}	0.6 ± 0.0^{a}
Mean stock weight ($g\cdot fish^{-1}$)	4.7 ± 1.9^{a}	4.9 ± 0.3^{a}
Harvest number	87.8 ± 7.6^{a}	81.7 ± 5.8^{a}
Total harvest weight (kg)	42.9 ± 4.0^{a}	21.6 ± 1.7^{b}
Mean harvest weight ($g\cdot fish^{-1}$)	489.5±18.4	265.0±13.8
Daily weight gain ($g\cdot fish^{-1}\cdot day^{-1}$)	3.0±0.1	1.6±0.1
Gross fish yield ($t\cdot ha^{-1}\cdot crop^{-1}$)	0.9 ± 0.1^{a}	0.4 ± 0.0^{b}
Net fish yield ($t\cdot ha^{-1}\cdot crop^{-1}$)	0.8 ± 0.1^{a}	0.4 ± 0.0^{b}
Survival (%)	70.3 ± 6.1^{a}	65.4 ± 4.7^{a}
Silver carp		
Stock number	175	133
Total stock weight (kg)	0.9 ± 0.1^{a}	0.7 ± 0.1^{a}
Mean stock weight ($g\cdot fish^{-1}$)	5.3 ± 0.5^{a}	5.3 ± 0.3^{a}
Harvest number	121.6 ± 13.3^{a}	88.0 ± 6.5^{b}
Total harvest weight (kg)	39.8 ± 4.3^{a}	28.1 ± 2.5^{a}
Mean harvest weight ($g\cdot fish^{-1}$)	317.9 ± 49.8^{a}	328.7 ± 33.9^{a}
Daily weight gain ($g\cdot fish^{-1}\cdot day^{-1}$)	1.9 ± 0.3^{a}	2.0 ± 0.2^{a}
Gross fish yield ($t\cdot ha^{-1}\cdot crop^{-1}$)	0.8 ± 0.2^{a}	0.6 ± 0.0^{b}
Net fish yield ($t\cdot ha^{-1}\cdot crop^{-1}$)	0.8 ± 0.2^{a}	0.5 ± 0.0^{b}
Survival (%)	69.5 ± 7.9^{a}	66.0 ± 0.0^{a}
Bighead carp		
Stock number	50	57
Total stock weight (kg)	1.2 ± 0.0^{a}	1.4 ± 0.2^{a}
Mean stock weight ($g\cdot fish^{-1}$)	24.4±0.8	23.6±0.9
Harvest number	50.0 ± 0.0^{a}	39.9 ± 4.2^{b}
Total harvst weight (kg)	16.5 ± 2.6^{a}	13.0 ± 1.6^{a}
Mean harvest weight ($g\cdot fish^{-1}$)	329.8 ± 52.5^{a}	322.5 ± 14.5^{a}
Daily waight gain ($g\cdot fish^{-1}\cdot day^{-1}$)	2.0 ± 0.3^{a}	2.0 ± 0.1^{a}
Gross fish yield ($t\cdot ha^{-1}\cdot crop^{-1}$)	0.3 ± 0.1^{a}	0.3 ± 0.0^{a}
Net fish yield ($t\cdot ha^{-1}\cdot crop^{-1}$)	0.3 ± 0.1^{a}	0.2 ± 0.0^{a}
Survival (%)	100.0 ± 0.0^{a}	70.0 ± 0.0^{b}
Grass carp		
Stock number	25	57
Total stock weight (kg)	0.4 ± 0.0^{b}	0.9 ± 0.1^{a}
Mean stock weight ($g\cdot fish^{-1}$)	15.8 ± 0.6^{a}	16.5 ± 0.0^{a}
Harvest number	24.9 ± 0.1^{b}	45.6 ± 4.8^{a}
Total harvest weight (kg)	8.1 ± 1.1^{b}	15.2 ± 2.7^{a}
Mean harvest weight ($g\cdot fish^{-1}$)	324.7 ± 44.1^{a}	320.5 ± 38.8^{a}
Daily weight gain ($g\cdot fish^{-1}\cdot day^{-1}$)	2.0 ± 0.3^{a}	1.9 ± 0.2^{a}
Gross fish yield ($t\cdot ha^{-1}\cdot crop^{-1}$)	0.2 ± 0.0^{a}	0.3 ± 0.1^{a}
Net fish yield ($t\cdot ha^{-1}\cdot crop^{-1}$)	0.2 ± 0.0^{a}	0.3 ± 0.1^{a}

Survival (%)	99.6±0.4 ^{a}	80.0±0.0^{b}
Rohu		
Stock number	75	85
Total stock weight (kg)	0.3±0.0 ^{a}	0.4±0.0 ^{a}
Mean stock weight (g·fish^{-1})	4.5±0.1 ^{a}	4.5±0.1 ^{a}
Harvest number	75.0±0.0 ^{a}	68.4±6.3 ^{a}
Total harvest weight (kg)	9.5±1.3^{b}	17.4±2.9 ^{a}
Mean harvest weight (g·fish^{-1})	126.4±16.8 ^{a}	249.2±25.0 ^{a}
Daily weight gain (g·fish^{-1}·day^{-1})	0.8±0.1^{b}	1.5±0.2 ^{a}
Gross fish yield (t·ha^{-1}·crop^{-1})	0.2±0.0 ^{a}	0.3±0.1 ^{a}
Net fish yield (t·ha^{-1}·crop^{-1})	0.2±0.0 ^{a}	0.3±0.1 ^{a}
Survival (%)	100.0±0.0 ^{a}	80.0±0.0^{b}
Mrigal		
Stock number	50	63
Total stock weight (kg)	0.2±0.0^{b}	0.4±0.0 ^{a}
Mean stock weight (g·fish^{-1})	4.7±0.2 ^{a}	5.5±0.0 ^{a}
Harvest number	50.0±0.0 ^{a}	52.1±8.0 ^{a}
Total harvest weight (kg)	7.1±1.2^{b}	12.3±2.2 ^{a}
Mean harvest weight (g·fish^{-1})	142.0±25.4^{b}	234.4±9.3 ^{a}
Daily weight gain (g·fish^{-1}·day^{-1})	0.9±0.2^{b}	1.4±0.1 ^{a}
Gross fish yield (t·ha^{-1}·crop^{-1})	0.1±0.0^{b}	0.2±0.0 ^{a}
Net fish yield (t·ha^{-1}·crop^{-1})	0.1±0.0^{b}	0.2±0.0 ^{a}
Survival (%)	100.0±0.0 ^{a}	82.4±11.5 ^{a}
Tilapia		
Stock number	150.0	-
Total stock weight (kg)	0.6±0.0	-
Mean stock weight (g·fish^{-1})	3.8±0.1	-
Harvest number	150.0±0.0	-
Total harvest weight (kg)	18.4±2.9	-
Mean harvest weight (g·fish^{-1})	122.6±19.0	-
Daily weight gain (g·fish^{-1}·day^{-1})	0.7±0.1	-
Gross fish yield (t·ha^{-1}·crop^{-1})	0.4±0.1	-
Net fish yield (t·ha^{-1}·crop^{-1})	0.4±0.1	-
Survival (%)	100.0±0.0	-
Sahar		
Stock number	50	-
Total stock weight (kg)	0.5±0.0	-
Mean stock weight (g·fish^{-1})	10.1±0.2	-
Harvest number	50.0±0.0	-
Total harvest weight (kg)	1.3±0.3	-
Mean harvest weight (g·fish^{-1})	26.5±5.6	-
Daily weight gain (g·fish^{-1}·day^{-1})	0.03±0.01	-
Gross fish yield (t·ha^{-1}·crop^{-1})	0.02±0.01	-
Net fish yield (t·ha^{-1}·crop^{-1})	100.0±0.0	-
Survival (%)	100±0.0	-

Table 7. Combined performance of carps, Nile tilapia and sahar in each treatment. Data based on 500 m^2 pond area. Mean values with different superscripts in the same row were significantly different ($P < 0.05$).

Parameters	Treatments	
	Carp+Tilapia+Sahar	Carps only
Gross fish yield ($t \cdot ha^{-1} \cdot crop^{-1}$)	$2.9±0.4^{a}$	$2.2±0.1^{b}$
Net fish yield ($t \cdot ha^{-1} \cdot crop^{-1}$)	$2.8±0.4^{a}$	$2.1±0.1^{b}$
Gross fish yield ($t \cdot ha^{-1} \cdot yr^{-1}$)	$5.8±0.8^{a}$	$4.4±0.2^{b}$
Net fish yield ($t \cdot ha^{-1} \cdot yr^{-1}$)	$5.6±0.8^{a}$	$4.2±0.2^{b}$
Overall survival (%)	$89.9±2.3^{a}$	$74.0±2.4^{b}$
Apparent food conversion ratio	$2.2±0.3^{a}$	$2.6±0.4^{a}$

Table 8. Overall mean and range values of water quality parameters in each treatment.

Parameters	Treatments	
	Carp+Tilapia+Sahar	Carps only
Temperature (°C)	27.4±2.4 (21.3 – 35.1)	28.3±2.6 921.0 – 34.5)
Dissolved oxygen ($mg \cdot L^{-1}$)	3.4±0.2 (0.3 – 6.7)	3.4±0.2 (1.4 – 5.1)
pH	7.6 (7.1 – 9.0)	7.5 (7.0 – 8.3)

Table 9. Economic analysis (in USD) for each treatment. Data based on 500 m^2 pond area. Mean values in a row with the same superscript are not significantly different ($\alpha = 0.05$).

Parameters	Treatments	
	Carp+Tilapia+Sahar	Carps only
Seed	16.0±0.0	13.2±0.1
Feed	97.9±5.0	63.9±2.3
Lime	5.0±0.0	5.2±0.1
Fertilizer	31.0±0.1	29.2±0.8
Water filling, Feeding Tray	6.5±0.1	6.6±0.1
Total input	156.5±5.0	118.0±2.5
Total output	317.4±22.3	208.0±12.9
Gross margin	$161.0±18.4^{a}$	$90.0±12.5^{b}$
Gross margin/ha	$3219±367^{a}$	$1800±250^{a}$

DISCUSSION

This study was carried out to demonstrate the role of Nile tilapia and sahar in improving the productivity of carp polyculture. In both trials, addition of Nile tilapia and sahar did not have any adverse effect on growth and production of all carp species as well as in pond water quality. This result suggests that tilapia and sahar did not have competition for pond resources with any carp species.

The growth rates of all carp species were almost similar in both trials. However, the average growth rate of carp species in all treatments was lower than reported by previous studies in carp polyculture (da Silva et al. 2008, Rai et al. 2008, Jaiswal 2010). Lower growth rate of carps in the present study might be due to lower average temperature during experiment period. In the first trial, the daily weight gain of Nile tilapia and sahar were 0.6 and 0.4 g, respectively, whereas in the second trial, the daily weight gain of Nile tilapia and sahar were 0.7 and 0.03 g, respectively. The daily weight gain of Nile tilapia in both trials was higher than grass carp-tilapia polyculture system (0.2-0.5 g) (Pandit et al. 2004) and similar with tilapia-sahar polyculture systems (0.6-0.9 g) (Shrestha et al. 2011), but lower than tilapia-sahar polyculture systems (1.15 g) (Acharya et al. 2007). Similarly, the daily weight gain of sahar in the first trial was higher than tilapia-sahar polyculture systems (0.3-0.4 g) (Shrestha et al. 2011) and almost similar to values (0.55-0.77 g) achieved in other systems (Islam 2002).

In the first trial, growth and production of original stock of Nile tilapia in T_2 (carp-tilapia) and T_3 (carp-tilapia-sahar) did not differ significantly suggesting that sahar did not affect the growth and production of Nile tilapia. However, production parameters like total harvested weight, extrapolated GFY and NFY were significantly affected by addition of sahar. This may be attributed to the fact that sahar consumes newly recruited tilapia. Total number and weight of small tilapia in carp-tilapia treatment (T_2) was significantly higher than that in carp-tilapia-sahar treatment (T_3). However, total number and weight of large tilapia recruits in T_2 and T_3 did not varied significantly. This may due to recruitment during nonpiscivorous stage of stocked sahar. Shrestha et al. (2011) also reported that there was significant lower average recruit number and weight of Nile tilapia in treatment with sahar than tilapia monoculture. Jaiswal (2010) also showed that average number and weight of tilapia recruits was lower in treatments with sahar than tilapia and carp only. Several other studies have also shown that number and weight of recruited Nile tilapia is lower in ponds with predator species (Yi et al. 2004, de Graaf et al. 2005, Acharya et al. 2007, Poudel et al. 2007, Jaiswal 2010, Shrestha et al. 2011).

In the farm trial, the combined gross fish yield, net fish yield and gross margin were significantly higher in polyculture of carps, tilapia and sahar treatment compared to polyculture of only carps.

Water quality was not significantly affected by stocking densities of fishes in species combination of carps, carp-tilapia, carp-tilapia-sahar polyculture in ponds, as water quality parameters did not differed significantly among treatments. Most water quality parameters in both trials were within acceptable ranges for fish culture (Boyd 1990).

CONCLUSION

Adding Nile tilapia and sahar did not affect the growth and production of carp species if included in carp polyculture system. However, adding these species can increase the total productivity in terms of GFY and NFY. Also, the problem of tilapia recruitment can be addressed by the introduction of sahar in polyculture. Thus, it can be concluded that Nile tilapia and sahar can be added in carp polyculture ponds without affecting the productivity of carp species.

QUANTIFIED ANTICIPATED BENEFITS

On-station experiment showed 25.5% increase in yield and in on-farm trial with six farmers showed 33.3% increase with this new production system.

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