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A COMPARISON OF MONOCULTURE AND POLYCULTURE OF NILE TILAPIA (*Oreochromis niloticus*) WITH CARPS AND SAHAR (*Tor putitora*)

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ABSTRACT
Addition of Nile tilapia (*Oreochromis niloticus*) and sahar (*Tor putitora*) in carp-polyculture, and tilapia monoculture systems was tested. The experiment was conducted at the Agriculture and Forestry University, Chitwan, Nepal in 12 earthen ponds of 150 m^2 for 185 days. The experiment was conducted in a completely random design with four treatments in triplicate: a) Carp-polyculture (10,000/ha) + mixed-sex tilapia (3,000/ha) + sahar (1,000/ha) (T_1); b) Carp-polyculture + monosex tilapia (3,000/ha) (T_2); c) Monosex tilapia at 10,000/ha with fertilization only (T_3); and d) Monosex tilapia at 20,000/ha with fertilization and feeding (T_4). Silver carp, bighead carp, common carp, grass carp, rohu and mrigal were stocked in all ponds as of normal practice. The ponds were fertilized weekly with urea and DAP. Fish were fed daily with 26% CP feed at 2% body weight. Combined net fish yield was significantly higher ($p<0.05$) in T_4 (3.77±0.23 t/ha/crop) compared to T_3 (1.03±0.14 t/ha/crop); there was no significant difference among T_1 (2.82±0.23 t/ha/crop), T_2 (3.20±0.17 t/ha/crop) and T_4 (3.77±0.23 t/ha/crop). The mean harvest size, daily growth, GFY and NFY of monosex Nile tilapia in T_4 were significantly higher than in T_3. The gross profit was significantly higher in T_4 compared to T_3 without any significant difference between T_1 and T_2.

Keywords: Nile tilapia, Carps, Sahar, Polyculture

INTRODUCTION
Semi-intensive carp polyculture is an established fish culture system in tropical and subtropical regions of Nepal, using fertilized ponds with supplemental feed (Shrestha et al. 2022). The commonly cultured carp species include silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Hypophthalmichthys (Aristichthys) nobilis*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*). All six species are recommended in certain ratios with a combined density of 10,000-12,000 fish/ha, but fingerlings of all species are rarely available when needed for stocking, often due to variations in the breeding seasons of these species. The typical number of species cultured ranges from four to six. The annual pond yield of this semi-intensive carp polyculture system averages only 4.91 t/ha (Rijal and Jha 2020). The addition of other proven species (such as Nile tilapia, *Oreochromis niloticus* and Sahar, *Tor putitora*) with increased stocking density into the existing carp production system could increase productivity up to 57% and net returns by 61% (Shrestha et al. 2012; Shrestha et al. 2018) without any additional inputs. Since tilapia consume plankton, they also improve water quality in ponds and in effluents at harvest. Such improvements in water quality, larger economic gain, and production of fish with no further inputs all enhance the sustainability of an aquaculture system environmentally and economically. Sahar is a native endangered fish species (IUCN 2017). Addition of sahar into carp polyculture can aid in their conservation, utilization of pond resources and control of excessive Nile tilapia recruitment in carp ponds (Shrestha et al. 2011).

Previously, we conducted an experiment incorporating tilapia into carp polyculture. The results showed significant increases in yield (29%) and profit margin (81%) when tilapia and sahar were added to carp polyculture (Shrestha et al. 2018). Overall production was still relatively low, about four tons per ha annually. This production is lower than monosex tilapia culture in ponds in Thailand, where we have achieved annual yields of about 5 tons per ha with only fertilizer inputs and up to 20 tons per ha in fed ponds (Diana 2012). Monoculture of tilapia could possibly outperform polyculture with carps in Nepal, as well, both in terms of total production and economic returns. It is not possible to directly transfer results on monoculture of tilapia from Thailand to Nepal, given the generally cooler and more seasonal climate in Nepal. Therefore, the purpose of this experiment is to examine monoculture of tilapia along with inclusion of tilapia in polyculture as techniques to best incorporate tilapia into the aquaculture industry in Nepal. Since sahar is an endangered species (IUCN 2017), any success in rearing them could either relieve pressure on wild populations as a food source or could be used to supplement wild populations by stocking to improving sustainability of aquaculture in Nepal. The objectives of this study were to test a carp-tilapia-sahar polyculture and monosex tilapia culture system; to evaluate the culture potential of sahar and monosex tilapia to farmers; and to develop partial enterprise budgets of costs and values of fish crops among treatments.

MATERIALS AND METHODS

The experiment was conducted at the fish farm of Agriculture and Forestry University, Rampur, Chitwan, Nepal in twelve earthen ponds of 150 m^2 for 185 days (1 June to 3 December 2017). The experiment was conducted in a completely randomized design with four treatments in triplicate. The treatments were: a) Existing carp polyculture (10,000/ha) + mixed-sex tilapia (3,000/ha) + sahar (1,000/ha) (T_1); b) Existing carp polyculture and monosex tilapia at 3,000/ha (T_2); c) Monosex tilapia at 10,000/ha with fertilization only (T_3); and d) Monosex tilapia at 20,000/ha with fertilization and feeding (T_4). Silver carp, bighead carp, common carp, grass carp, rohu and mrigal of mean stocking size 3.2 and 3.3, 0.6 and 0.6, 13.6 and 12.5, 5.9 and 6.2, 21.7 and 20.6, 11.1 and 11.9 g, respectively were stocked in T_1 and T_2 at the ratio of 3.5:1:2.5:0.5:1.5:1. Mixed-sex Nile tilapia and sahar of 1.9 and 2.1 g size were added in T_1. Similarly, the stocking size for all-male tilapia in T_2, T_3, and T_4 were 0.9, 1.2, and 0.9 g, respectively. All experimental ponds were completely drained and treated with hydrated lime [$Ca(OH)_2$] at the rate of 450 kg per ha. The ponds were sun dried for 2-3 days then filled with canal water. Ponds were then fertilized at 4 kg N and 1 kg P/m^2/day with di-ammonium phosphate (DAP) (18% N and 46% P_2O_5) and urea (46% N). Fingerlings were stocked one week after pond fertilization. Subsequent fertilizations were done on a weekly basis. Feeding was done with commercial pellet feed (Machapuchhre Feed Industry, Kapilvastu, Nepal) at 2% of total carp biomass per day. The proximate composition of feed was 90.0% dry matter, 26.6% crude protein, 8.6% crude fiber, 2.4% ether extract and 5.4% total ash. Feeding was done once in the morning between 9 and 10 a.m. The quantity of feed was adjusted monthly based on fish sampling. Sampling of fish was done monthly from each pond starting 30 days after stocking. During sampling about 10% of the stocked population of each species was weighed to calculate feed quantity for next month, assuming 100% survival. For final harvest, all ponds were drained by pumping and all fish were harvested and weighed. Weekly and biweekly measurements of water quality parameters were conducted at 6-8 a.m. Water temperature, dissolved oxygen (DO), pH, and Secchi disk depth were measured in situ weekly using a dissolved oxygen meter (Lutron DO-5519), pH meter (Lutron pH-222) and Secchi disk, respectively. Water samples were collected biweekly from each pond using a plastic column sampler and analyzed for total alkalinity, total ammonium nitrogen (TAN), soluble reactive phosphorous (SRP), and chlorophyll a (APHA 1985). Proximate analysis of feed was done using methods provided in AOAC (1980). Simple economic analysis was done to determine economic returns from each treatment (Shang 1990). The economic analysis was mainly based on farm gate price for harvested fish and current local market prices for all other inputs in Nepal. Farm gate prices of sahar, tilapia and carps were 600, 250 and 250 NRs per kg, respectively. Prices for sahar, mixed-sex tilapia, and monosex tilapia fingerlings were 5, 1, and 2 NRs per piece, respectively. Prices for common carp, silver carp, bighead carp, grass carp, rohu and mrigal fingerlings were 5, 1, 0.5, 2, 5 and 3 NRs per piece, respectively. Prices for DAP, urea and feed were 50, 22 and 20 NRs per kg, respectively.

The data were analyzed by one-way ANOVA using SPSS (V 16.0). For significant differences in growth parameters among different treatments, LSD was used to compare the means. For testing different growth and production parameters of carps, a T-test was used. For all analysis alpha was set at 0.05.

RESULTS

The production of all carps was not significantly different between T_1 and T_2 ($p>0.05$; Table 1). The production of all-male monosex tilapia in T_4 was significantly higher than in T_3 ($p<0.05$). Similarly, the extrapolated gross fish yield (GFY) of tilapia in T_2 was significantly higher than T_1 ($p<0.05$). The combined extrapolated GFY of all species excluding and including tilapia recruits was significantly lower in T_3 than other treatments ($p<0.05$). Similarly, the combined extrapolated net fish yield (NFY) of all species excluding tilapia recruits was significantly lower in T_3 than T_4 ($p<0.05$). The gross and net fish yields for monosex tilapia without feed was significantly lower than monosex tilapia with feed and carp treatments. The apparent food conversion ratio (AFCR) was significantly lower in T_4 compared to T_1 and T_2 without any significant differences between T_1 and T_2 (Table 1).

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

	Treatments			
Parameters	**T_1**	**T_2**	**T_3**	**T_4**
Extrapolated GFY (t/ha/crop)				
Carps	2.42 ± 0.20^a	2.58 ± 0.14^a	-	-
Tilapia	0.49 ± 0.04^a	0.72 ± 0.09^b	1.04 ± 0.14^c	3.79 ± 0.12^d
Sahar	0.02 ± 0.00	-	-	-
Combined excluding tilapia recruits	2.93 ± 0.46^b	3.29 ± 0.17^b	1.04 ± 0.14^a	3.79 ± 0.12^b
Combined including tilapia recruits	3.00 ± 0.22^b	3.29 ± 0.17^b	1.04 ± 0.14^a	3.79 ± 0.12^b
Extrapolated NFY (t/ha/crop) excluding tilapia recruits	2.82 ± 0.23^{ab}	3.20 ± 0.17^{ab}	1.03 ± 0.14^a	3.77 ± 0.23^b
AFCR	2.42 ± 0.28^b	2.09 ± 0.14^b	-	1.86 ± 0.07^a

Each carp species showed similar production parameters in all treatments, indicating the addition of tilapia and sahar did not affect overall carp production (Table 2). There were no significant differences in mean harvest weight, total harvest weight, mean daily weight gain (DWG), survival rate, extrapolated GFY, and extrapolated NFY of different carp species among treatments. However, mean harvest size, daily weight gain, gross fish yield and net fish yield of monosex Nile tilapia in T_4 were significantly higher than in T_3 ($p<0.05$).

Table 2. Growth and production parameters (mean ±SE) in different treatments. Data based on a 150 m^2 pond for 185 days culture period. Mean values in a row with the same superscript are not significantly different ($\alpha = 0.05$).

Parameter	Treatment			
	T_1	T_2	T_3	T_4
Common Carp				
Mean stocking weight (g)	13.6±1.1[a]	12.5±0.4[a]	-	-
Mean harvest weight (g)	385.6±46.8[a]	397.0±10.4[a]	-	-
DWG (g/day)	2.01±0.26[a]	2.08±0.05[a]	-	-
Survival (%)	67.5±8.9[a]	71.1±10.6[a]	-	-
GFY (t/ha/crop)	0.64±0.04[a]	0.71±0.09[a]	-	-
NFY (t/ha/crop)	0.61±0.04[a]	0.68±0.09[a]	-	-
Silver Carp				
Mean stocking weight (g)	3.2±0.2[a]	3.3±0.2[a]	-	-
Mean harvest weight (g)	319.6±15.8[a]	370.3±13.6[a]	-	-
DWG (g/day)	1.71±0.08[a]	1.08±0.07[a]	-	-
Survival (%)	39.0±2.3[a]	29.6±4.9[a]	-	-
GFY (t/ha/crop)	0.44±0.02[a]	0.39±0.08[a]	-	-
NFY (t/ha/crop)	0.43±0.02[a]	0.38±0.08[a]	-	-
Bighead Carp				
Mean stocking weight (g)	0.6±0.0[a]	0.6±0.0[a]	-	-
Mean harvest weight (g)	470.4±39.6[a]	473.7±47.0[a]	-	-
DWG (g/day)	2.54±0.21[a]	2.56±0.25[a]	-	-
Survival (%)	68.9±5.9[a]	71.1±8.9[a]	-	-
GFY (t/ha/crop)	0.32±0.00[a]	0.33±0.01[a]	-	-
NFY (t/ha/crop)	0.32±0.00[a]	0.33±0.01[a]	-	-
Grass Carp				
Mean stocking weight (g)	5.9±0.3[a]	6.2±0.4[a]	-	-
Mean harvest weight (g)	446.0±195.5[a]	635.9±47.7[a]	-	-
DWG (g/day)	2.38±1.06[a]	3.40±0.26[a]	-	-
Survival (%)	79.2±30.1[a]	62.5±12.5[a]	-	-
GFY (t/ha/crop)	0.16±0.06[a]	0.21±0.03[a]	-	-
NFY (t/ha/crop)	0.16±0.06[a]	0.20±0.04[a]	-	-
Rohu				
Mean stocking weight (g)	21.7±1.2[a]	20.6±0.7[a]	-	-
Mean harvest weight (g)	396.3±40.2[a]	411.3±62.5[a]	-	-
DWG (g/day)	2.02±0.22[a]	2.11±0.34[a]	-	-
Survival (%)	94.2±5.8[a]	95.7±9.1[a]	-	-

Parameter	Treatment			
	T1	T2	T3	T4
GFY (t/ha/crop)	0.57±0.05[a]	0.59±0.05[a]	-	-
NFY (t/ha/crop)	0.53±0.05[a]	0.56±0.05[a]	-	-
Mrigal				
Mean stocking weight (g)	11.1±0.3[a]	11.9±0.4[a]	-	-
Mean harvest weight (g)	471.1±45.6[a]	480.0±42.1[a]	-	-
DWG (g/day)	2.49±0.25[a]	2.53±0.23[a]	-	-
Survival (%)	60.0±3.0[a]	73.3±3.9[a]	-	-
GFY (t/ha/crop)	0.29±0.04[a]	0.35±0.02[a]	-	-
NFY (t/ha/crop)	0.27±0.04[a]	0.34±0.02[a]	-	-
Nile tilapia				
Mean stocking weight (g)	1.9±0.1	0.9±0.0	1.2±0.0	0.9±0.1
Mean harvest weight (g)	267.1±28.4	356.5±33.6	152.1±29.2[a]	281.7±4.8[b]
DWG (g/day)	1.43±0.15	1.92±0.18	0.82±0.16[a]	1.52±0.03[b]
Survival (%)	62.2±2.3	66.7±2.6	70.0±5.1[a]	67.2±1.9[a]
GFY (t/ha/crop)	0.49±0.04	0.72±0.09	1.04±0.14[a]	3.79±0.12[b]
NFY (t/ha/crop)	0.49±0.04	0.71±0.09	1.03±0.14[a]	3.77±0.12[b]
Sahar				
Mean stocking weight (g)	12.1±1.1	-	-	-
Mean harvest weight (g)	35.7±1.9	-	-	-
DWG (g/day)	0.13±0.01	-	-	-
Survival (%)	68.9±5.9	-	-	-
GFY (t/ha/crop)	0.02±0.00	-	-	-
NFY (t/ha/crop)	0.01±0.00	-	-	-

There was no significant difference in average temperature, dissolved oxygen, total alkalinity, total ammonium nitrogen, soluble reactive phosphorous and chlorophyll-a among treatments during the experimental period (Table 3)

Table 3. Water quality parameters (mean ±SE with range in parentheses) in different treatments.

Parameters	Treatments			
	T1	T2	T3	T4
Water temperature (°C)	28.3±0.2 (21.2-32.2)	28.2±0.2 (21.7-31.6)	28.1±0.1 (21.5-31.6)	28.1±0.2 (21.5-31.6)
Dissolved oxygen (mg/L)	2.6±0.1 (0.7-7.1)	2.7±0.3 (0.7-6.3)	2.6±0.2 (0.5-5.7)	3.6±0.3 (0.7-8.3)
pH	7.2 (6.5-7.9)	7.1 (6.1-8.0)	7.2 (6.2-7.9)	7.2 (6.5-8.2)
Total alkalinity (mg/L as $CaCO_3$)	146.4±13.0 (86.8-178.5)	143.8±2.2 (107.5-179.4)	145.3±6.7 (104.1-199.7)	141.0±9.3 (104.6-180.9)
Soluble reactive phosphorous (mg/L)	0.43±0.00 [ab] (0.05-0.96)	0.46±0.00 [b] (0.01-1.08)	0.47±0.02 [b] (0.14-1.63)	0.37±0.03 [a] (0.06-0.96)
Total ammonium nitrogen (mg/L)	0.44±0.0 (0.05-1.27)	0.39±0.02 (0.08-1.20)	0.42±0.0 (0.04-1.10)	0.33±0.05 (0.04-0.88)
Chlorophyll-a (mg/m^3)	78.1±27.7 (15.9-216.6)	73.7±9.7 (19.0-210.2)	80.8±10.3 (12.7-206.3)	48.9±4.8 (15.1-103.1)

The gross margin for monosex tilapia with feed was significantly higher than monosex tilapia without feed, while carp treatments were intermediate in gross margin. The variable costs in all treatments consisted of seed, feed, lime, urea, and DAP (Table 4). Cost of seed was significantly different among treatments ($p<0.05$), whereas cost of feed was not significantly different among fed treatments ($p>0.05$). There was no significant difference in all other variable costs among different treatments ($p>0.05$). Total input cost and total output were significantly lower in T_3 than other treatments. The gross profit margin was significantly higher in T_4 (463,942±31,804 NPR/ha) compared to T_3 (174,940±35,836 NPR/ha) without any significant difference between T_1 and T_2 ($p<0.05$; Table 4).

Table 4. Economic analysis (NPR) for each treatment. Data based on a 150 m^2 pond area and culture period of 150 days. Mean values in a row with the same superscript are not significantly different ($\alpha = 0.05$).

Variable	Treatment			
	T_1	T_2	T_3	T_4
Seed	662±0.0^d	473±0.0^b	304±0.0^a	598±0.0^c
Feed	5440±326 ^{a}	5386±105 ^{a}	0.0±0.0	5660±74 ^{a}
Lime	136±0.0 ^{a}	136±0.0 ^{a}	136±0.0 ^{a}	136±0.0 ^{a}
Urea	306±0.0 ^{a}	306±0.0 ^{a}	306±0.0 ^{a}	306±0.0 ^{a}
DAP	536±0.0 ^{a}	536±0.0 ^{a}	536±0.0 ^{a}	536±0.0 ^{a}
Total Input	7088±326 ^{b}	6846±105 ^{b}	1281±0.0 ^{a}	7245±74 ^{b}
Total Output	11130±861 ^{b}	12348±630^{bc}	3906±536 ^{a}	14196±441^c
Gross Margin	4042±1071 ^{ab}	5502±704 ^{ab}	2625±536 ^{a}	6962±472^b
Gross Margin per ha	269756±71390^{ab}	366650±47198 ^{ab}	174940±35836 ^{a}	463942±31804^b

DISCUSSION

This study was carried out to expand the technology developed through AquaFish research on carps, tilapia and sahar production as well as technology of monosex tilapia production to farmers in order to demonstrate alternative fish production models (Shrestha et al. 2012; Shrestha et al. 2018). An on-station experiment on monoculture and polyculture systems, using carp with the addition of tilapia and sahar was conducted, to determine the most practical system for farm adoption. We observed that the addition of Nile tilapia and sahar in carp polyculture had no adverse effect on growth and production of all carp species, or in pond water quality. This results suggest that tilapia and sahar did not compete for pond resources with any carp species.

The daily weight gain of mixed-sex Nile tilapia and sahar were 1.43 and 0.13 g, respectively, which is comparable or slightly higher than in previous experiments. The daily weight gain of Nile tilapia in polyculture was higher than a grass carp-tilapia polyculture system (0.2-0.5 g; Pandit et al. 2004), carp-tilapia-sahar polyculture system (0.63-0.70 g; Bhandari et al. 2016), tilapia-sahar polyculture system (0.6-0.9 g; Shrestha et al. 2011), and tilapia-sahar polyculture system (1.15 g; Acharya et al. 2007). The daily weight gain of sahar was quite low in the present experiment. The quality of feed (low protein; 26.6% CP) may have contributed to slow growth of sahar. Sundar et al. (1998) reported better growth, survival, and FCR of sahar were achieved from feed with 45.4% crude protein among diets with 21.4% to 50.2% crude protein. In a similar study, Joshi et al. (1989) reported that 35% crude protein was best for growth and feed efficiency of sahar. Good growth rates of all carp species were achieved in all carp treatments. The average growth rate of carp species in all treatments was higher than reported by previous studies in carp polyculture (Rai et al. 2008; Jaiswal 2010) as well as in our previous on-farm and farmer's field trials (Bhandari et al. 2016).

The combined gross fish yield in carp treatments (5.8-6.5 t/ha/year) was higher than the national average of carp polyculture (4.91. t/ha/year) (Rijal and Jha 2020). The hypothesis that addition of tilapia and sahar would increase the yield and profit from polyculture ponds was supported by the results of this experiment. However, production and profit of monosex tilapia without feed was quite low. Diana (2012) achieved annual yields of monosex tilapia of about 5 tons/ha with only fertilizer inputs. Although the production of monosex tilapia with feed was higher than all carp treatments and monosex tilapia without feed treatment, this was still quite low than reported by Diana (2012). Although the growth rate was satisfactory (0.82-1.52 g/day), the poor production of monosex tilapia in both feed and non-feed systems in the present experiment was associated with poor survival of fish (67-70%, compared to over 90% in other systems). Mandal et al. (2020) reported a growth rate of 1.52 g/day of monosex Nile tilapia stocked at 2 fish/m^2 in a feeding system in hapa.

The number of tilapia recruits in the carp-tilapia-sahar system was quite low. This is due to the piscivorous nature of the stocked sahar. Shrestha et al. (2011) reported there was a significantly lower average recruit number and weight of Nile tilapia in treatments with sahar than in tilapia monoculture. Jaiswal (2010) also showed that the average number and weight of tilapia recruits in treatments with sahar was lower than with tilapia and carp only. Water quality was not significantly affected by stocking densities of fishes in species combination of carp-tilapia-sahar polyculture in ponds, as water quality parameters did not differ significantly among treatments. Most water quality parameters were within acceptable ranges for fish culture (Boyd 1990). Results of this experiment clearly indicates production, productivity and gross margin is better in tilapia and sahar incorporated carp-polyculture and tilapia monoculture with feed and fertilized system than only carp polyculture system.

CONCLUSION

The result of the present study demonstrates that three of the culture systems (polyculture of carps with mixed sex tilapia and sahar, carps with monosex tilapia, and monosex tilapia with fertilization and feeding) performed similarly and enhanced productivity and income compared to the currently used carp polyculture system in Nepal. Tilapia either in monoculture or in polyculture proved suitable additional species in the aquaculture for Nepal. It has been confirmed that incorporating tilapia can enhance the overall performance of the carp polyculture system in Nepal. As carp polyculture is the established culture system, adding species will be easier to adopt by fish farmers. While immediate adoption of a monoculture of tilapia be more challenging for farmers who have been practicing carp polyculture for decades, indications of higher production efficiency and profit will serve as initial steps in developing that system. Inclusion of sahar in polyculture will help to conserve sahar populations as well as in controlling tilapia recruitment in mixed sex tilapia culture where monosex fry is not available.

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