Production of Periphyton to Enhance Yield in Polyculture Ponds with Carps and Small Indigenous Species

Sustainable Feed Technology and Nutrient Input Systems/Experiment/13SFT08UM

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ABSTRACT

An experiment was conducted at Agriculture and Forestry University, Chitwan, Nepal to compare fish production between carp-SIS polyculture and periphyton-enhanced carp-SIS polyculture in order to develop a cost-effective means to increase fish production. The experimental period was 210 days from 24 August 2014 to 28 March 2015. The experiment included four treatments: T_1 (carp+100% supplemental feed), T_2 (carp+SIS+100% supplemental feed), T_3 (carp+SIS+50% supplemental feed + bamboo substrate at 1 % of pond surface area) and T_4 (carp+SIS+bamboo substrate with no feed), each with three replications. Silver carp (*Hypophthalmichthys molitrix*), bighead carp (*Aristichthys nobilis*), grass carp (*Ctenopharyngodon idella*), common carp *(Cyprinus carpio),* rohu *(Labeo rohita)* and mrigal *(Cirrhina mrigala)* were stocked at a ratio of 4:1:4:3:5 at a rate of 15,000 fish/ha. Additionally, two small indigenous species (SIS) dedhuwa *(Esomus danricus)* and pothi *(Puntius sophore)* were stocked at a ratio of 1:1 at density of 50,000 fish/ha. Carps were fed with freshly made dough of mustard oil cake and rice bran (1:1) daily at 5% of body weight; whereas, grass carp was fed daily with grass at 50% body weight. Growth and yield of common carp was higher in T_3 than the other treatments, indicating it benefits from both periphyton and supplementary feed for better growth. Growth and production of grass carp were significantly higher in ponds without substrate. Total carp yield and combined NFY were higher in T_3, due to higher survival and growth rate of carps caused by periphyton and supplementary feed. Production of SIS was lower in substrate ponds, indicating that they did not use periphyton as a significant food source. Gross margin was highest in T_3, intermediate in T_4, and lowest in T_2. T_3 was found to be the best among treatments, based on fish production and profit.

INTRODUCTION

The government of Nepal has recognized that chronic malnutrition is a major problem in the country (UNICEF, 2012). With the nutrition problem, there is a need to develop an environmentally sustainable and cost-effective means of year-round food production that provides adequate nutrients and improves household income to rural poor farmers. Since 2008, the Institute of Agriculture and Animal Science has been promoting an innovative and environmentally sustainable household fish-production system, "carp-SIS polyculture," to improve the nutrition of poor women and children in Terai region (Rai et al. 2012). The approach includes increased intake of nutrient-rich SIS to improve health and nutrition of women and children. Vitamin A, calcium, zinc, and iron are found to be much higher in the eyes, head, organs, and viscera of SIS (Roos et al. 2006). Since SIS are eaten whole, there is no loss of nutrients from cleaning or as plate waste. Moreover, SIS are self-recruiting and can be harvested weekly and biweekly, favoring household consumption. Carp-SIS polyculture also provides additional income through the sale of surplus fish. The farming system including SIS raised fish production above that of the national average, doubled consumption rate of owners, and farmers earned Rs 3,025 per household in 270 days, which helped them to be empowered economically (Rai et al. 2012).

In commercial fish farming, feed alone accounts for approximately 60% of total input cost (Bhujel 2009), which is expensive to small-scale farmers, so it is essential to provide opportunities to reduce feed cost. Adding substrates such as bamboo to carp ponds can facilitate growth of periphyton, which serves as food for carp and increases their production. Since *rohu (Labeo rohita)*, catla (*Catla catla*), and *common carp (Cyprinus carpio)* are periphyton feeders (Rai and Yi, 2012), their growth and production are enhanced in ponds with added substrate for periphyton colonization compared to ponds without substrates (Azim et al. 2002, Rai et al. 2008). Azim et al. (2002) showed a 70% increase in rohu production in ponds with substrates for periphyton growth, compared to control ponds. Azim et al. (2004) showed a 59% increase in net yield for polyculture carp ponds with feed and periphyton enhancement, and a 28% increase in yield for periphyton enhancement only, compared to ponds with fertilizer only. Since the combination of species and type of feed influence the yield and income in such a system, it is necessary to test the full combination of feed inputs, periphyton enhancement, and production to truly understand the best system for commercial production (Diana, 2012). Therefore, we assessed the effect of periphyton enhancement on carp-SIS polyculture with reduced and without feeding systems in Chitwan, Nepal.

OBJECTIVES

Our overall objective was to compare fish production between carp-SIS polyculture and periphyton-based carp-SIS polyculture in order to develop a cost-effective means to increase fish production. Specific objectives included:

- To compare growth and yield of carps between carp polyculture and carp-SIS polyculture systems;
- To compare the growth and yield of carps and SIS with and without periphyton enhancement;
- To compare water quality among different polyculture systems; and
- To compare profitability among different polyculture systems.

MATERIALS AND METHODS

The experiment was conducted for 210 days (24 August 2014 to 28 March 2015) in 12 earthen ponds at the Teaching and Research Farm of Aquaculture and Fisheries Department, Agriculture and Forestry University, Rampur, Chitwan. The average area of an experimental pond was 150.9±4.1 m^2, ranging from 117.7–168.5 m^2.

The experiment was conducted using a completely randomized design. There were four treatments each, with three replicates. Treatments included: T_1 (carp+100% supplemental feed), T_2 (carp+SIS+100% supplemental feed), T_3 (carp+SIS+50% supplemental feed + bamboo substrate), and T_4 (carp+SIS+bamboo substrate with no feed).

Predatory fish were eradicated by applying bleaching powder at 250 kg/ha to ponds. After 15 days of bleaching, ponds were fertilized with inorganic fertilizer, urea, and DAP at 470 g/100 m^2 and 350 g/100 m^2. Bamboo substrate was installed for growth of periphyton in substrate treatment ponds (T_3 and T_4). Whole bamboo was procured from the AFU farm. These were split into three to five cm broad slats each, with an average length of one m. These slats were then tied onto a rectangular bamboo mat, using string with space between slats to allow fish to browse on attached periphyton. Bamboo mats were constructed and installed so that two mats covered an area equivalent to 1% of total pond surface area. Bamboo mats were suspended vertically in the water column with the top two edges tied to Styrofoam blocks serving as floats, and the bottom two edges tied to bricks serving as weights.

Stocking of fish was initiated seven days after fertilization. Ponds were stocked with silver carp (*Hypophthalmichthys molitrix*) (11.7±0.5 g), bighead carp (*Aristichthys nobilis*) (9.6±0.4 g), grass carp (*Ctenopharyngodon idella)* (4.8±0.2 g), common carp (1.1±0.1 g), rohu (0.8±0.0 g) and mrigal (*Cirrhinus cirrhosis*) (1.8±0.1 g) in all ponds at rates of 3000, 750, 2250, 3000, 3750 and 2250 fingerling/ha, respectively. Similarly, *pothi (Puntius sophore)* (2.2±0.1 g) and *dedhuwa (Esomus danricus)* (1.2±0.0 g) were also stocked at 25,000 fish/ha for each species in ponds of T_2, T_3, and T_4. Carp and SIS were fed with freshly made dough of mustard oil cake and rice bran (1:1). Feed was provided in traditional bamboo trays, placed in all feeding ponds every morning at 9:00–10:00 h. Feeding rate was 5% BW/day for the initial two months and was then reduced to 2% until the end of the experiment. Since the experiment was carried out during winter, feeding was done only when the feed of the previous day was consumed. In substrate ponds, half of the previous feeding rates was given in T_3 and no supplementary feed in T_4. Also, fertilization was done every two weeks to enhance production of periphyton and maintain the plankton population. Periodic fertilization with inorganic fertilizers was done at similar rate as before. Fertilizers were soaked and dissolved in water a few hours prior to application for better efficiency. Grass carp was fed daily with locally available grass at 50% body weight.

Temperature, dissolved oxygen (DO) and pH were measured every two weeks at 7:00–8:00 h, while transparency, total alkalinity, total ammonia nitrogen, soluble reactive phosphorus, and chlorophyll *a* were analyzed monthly at the AFU laboratory. Periphyton sampling from bamboo substrate was taken randomly from 1 cm^2 and analyzed using methods in Azim et al. (2001). Dry matter, ash content, and ash-free dry matter were estimated using methods from APHA (1980). Fish were sampled monthly for size and feed calculation for the next month. At least 20% of each species were netted and weighed. Final harvest was conducted on 26–28 March 2015 by completely draining ponds using diesel pumps. At final harvest all fish were counted and weighed to assess survival rate and production.

Economic return was calculated using gross margin analysis. Variable costs were estimated for carp seed, SIS seed, bleach, urea, DAP, bamboo, bamboo trays, and feed. Gross return was calculated based on product sold at farm gate prices.

Experimental data were evaluated with one-way analysis of variance (ANOVA) using SPSS (V 16.0) to find significant differences among treatments. Duncan's Multiple Range Test was used when significant differences were found. Differences were considered significant at an alpha level of 0.05. All means are given with ± 1 standard error (SE). Comparison of carp growth and production and of periphyton biomass (i.e., dry matter, ash, and ash-free dry matter) among treatments were done using student t-tests. Data on percent survival, as well as contribution of carp and SIS to total production, were analyzed after square root transformation of original data.

RESULTS

There was no significant difference (p>0.05) in mean values of all water quality parameters among different treatments (Table 1).

Table 1: Summary of water quality parameters in different treatments (mean±SE). In most tables, figures in parenthesis show the range, and superscripts of the same value in a row indicate no significant difference between the values.

Parameters	Unit	Treatment			
		T_1	T_2	T_3	T_4
Temperature	°C	23.0±0.0^a	23.0±0.1^a	23.0±0.1^a	23.0±0.1^a
		(14.1-31.6)	(14.1-31.6)	(14.2-32.2)	(14.1-32.1)
pH		6.6	6.5	6.6	6.6
		(5.5-8.3)	(5.7-8.3)	(5.8-8.8)	(5.5-9.3)
Dissolved Oxygen	mg/L	3.6±0.2^a	3.4±0.2^a	3.3±0.2^a	3.0±0.1^a
		(0.6-6.9)	(0.6-6.8)	(0.4-8.2)	(0.1-7.6)
Transparency	cm	25±5^a	23±2^a	21±1^a	21±1^a
		(20-40)	(20-30)	(20-30)	(20-30)
Alkalinity	mg/L as CaCO3	102.7±6.9^a	98.3±1.6^a	95.4±5.0^a	94.5±6.7^a
		(66.0-131.9)	(72.6-128.1)	(68.6-127.4)	(69.0-134.4)
Total Ammonium Nitrogen	mg/L	0.051±0.020^a	0.031±0.008^a	0.053±0.018^a	0.052±0.004^a
		(0.004-0.094)	(0.007-0.099)	(0.009-0.097)	(0.010-0.093)
Soluble Reactive Phosphorus	mg/L	0.030±0.011^a	0.026±0.007^a	0.035±0.004^a	0.020±0.004^a
		(0.004-0.048)	(0.004-0.053)	(0.016-0.049)	(0.003-0.051)
Chlorophyll-a	mg/m^3	20.5±5.8^a	20.9±6.1^a	21.5±1.1^a	23.4±1.0^a
		(8.0-32.6)	(6.4-43.8)	(14.4-27.3)	(17.6-33.7)

Dry matter (mg/cm^2), ash content (%), and ash-free dry matter (mg/cm^2) of periphyton produced on bamboo substrate in treatments T_3 and T_4 were also not significantly different between treatments (Table 2).

Table 2: Periphyton content in different treatments.

	Treatment	
Parameters	T_3	T_4
Dry Matter (mg/cm^2)	3.0±0.2^a	2.5±0.2^a
Ash Content (%)	21.7±1.1^a	22.0±0.2^a
Ash-free Dry Matter (mg/cm^2)	2.3±0.1^a	2.0±0.1^a

Total carp production and combined fish yield was significantly higher in T_3 with periphyton substrate, SIS, and carps than in T_4 (p<0.05), and was insignificantly higher than in the other two treatments (Table 3). SIS production was higher in T_2 with SIS and carps at 100% feed than in T_3 or T_4 (p<0.05). FCR was best (1.02) in T_3 compared to the other two feeding treatments (p<0.05). Among individual species, grass carp had highest production in T_1 and common carp in T_3, while all other species showed no differences among treatments.

Table 3: Growth performance of carps and SIS in different treatments.

Parameters	Treatments			
	T_1	T_2	T_3	T_4
Silver carp				
Initial mean weight (g/fish)	12.0 ± 0.2^{a}	10.3 ± 2.2^{a}	12.2 ± 0.1^{a}	12.2 ± 0.2^{a}
Initial total weight (g/100m^2)	355.9 ± 6.7^{a}	308.6 ± 66.1^{a}	365.9 ± 4.8^{a}	362.3 ± 2.9^{a}
Final mean weight (g/fish)	334.5 ± 97.7^{a}	278.8 ± 81.1^{a}	282.6 ± 13.0^{a}	327.4 ± 78.9^{a}
Final total weight (kg/100m^2)	6.0 ± 1.7^{a}	6.4 ± 1.6^{a}	7.1 ± 0.4^{a}	7.0 ± 0.8^{a}
DWG (g/fish/day)	1.5 ± 0.5^{a}	1.3 ± 0.4^{a}	1.3 ± 0.1^{a}	1.5 ± 0.4^{a}
TWG (kg/pond)	8.4 ± 2.9^{a}	9.5 ± 3.0^{a}	9.9 ± 0.6^{a}	10.7 ± 1.0^{a}
Survival (%)	65.0 ± 13.0^{a}	78.2 ± 3.4^{a}	84.7 ± 6.4^{a}	77.0 ± 9.9^{a}
Extrapolated GFY (t/ha/yr)	1.03 ± 0.29^{a}	1.11 ± 0.28^{a}	1.24 ± 0.07^{a}	1.22 ± 0.13^{a}
Extrapolated NFY (t/ha/yr)	0.97 ± 0.29^{a}	1.05 ± 0.29^{a}	1.18 ± 0.07^{a}	1.16 ± 0.13^{a}
Bighead carp				
Initial mean weight (g/fish)	10.7 ± 1.1^{a}	9.4 ± 0.5^{a}	9.6 ± 0.5^{a}	8.9 ± 0.4^{a}
Initial total weight (g/100m^2)	79.9 ± 8.0^{a}	70.0 ± 2.3^{a}	72.0 ± 2.3^{a}	67.9 ± 3.2^{a}
Final mean weight (g/fish)	459.3 ± 28.9^{a}	399.4 ± 62.0^{a}	466.5 ± 42.7^{a}	316.4 ± 55.8^{a}
Final total weight (kg/100m^2)	1.6 ± 0.1^{a}	1.8 ± 0.6^{a}	2.2 ± 0.2^{a}	1.8 ± 0.3^{a}
DWG (g/fish/day)	2.1 ± 0.1^{a}	1.9 ± 0.3^{a}	2.2 ± 0.2^{a}	1.5 ± 0.3^{a}
TWG (kg/pond)	2.1 ± 0.1^{a}	2.7 ± 0.9^{a}	3.1 ± 0.2^{a}	2.8 ± 0.5^{a}
Survival (%)	45.4 ± 2.5^{b}	58.9 ± 9.4^{ab}	63.6 ± 5.3^{ab}	75.6 ± 0.6^{a}
Extrapolated GFY (t/ha/yr)	0.27 ± 0.02^{a}	0.32 ± 0.10^{a}	0.38 ± 0.03^{a}	0.32 ± 0.05^{a}
Extrapolated NFY (t/ha/yr)	0.26 ± 0.02^{a}	0.31 ± 0.10^{a}	0.38 ± 0.03^{a}	0.30 ± 0.05^{a}
Grass carp				
Initial mean weight (g/fish)	4.9 ± 0.5^{a}	4.5 ± 0.5^{a}	5.1 ± 0.1^{a}	4.8 ± 0.3^{a}
Initial total weight (g/100m^2)	145.3 ± 16.4^{a}	133.6 ± 13.8^{a}	154.3 ± 4.6^{a}	141.4 ± 7.8^{a}
Final mean weight (g/fish)	465.4 ± 32.1^{a}	262.4 ± 24.8^{bc}	341.8 ± 81.9^{ab}	136.0 ± 39.0^{c}
Final total weight (kg/pond)	5.0 ± 0.5^{a}	2.9 ± 0.4^{b}	4.4 ± 0.1^{ab}	2.6 ± 1.0^{b}
DWG (g/fish/day)	2.2 ± 0.2^{a}	1.2 ± 0.1^{bc}	1.6 ± 0.4^{ab}	0.6 ± 0.2^{c}
TWG (kg/pond)	7.0 ± 0.0^{a}	4.2 ± 0.6^{ab}	6.2 ± 0.1^{ab}	3.9 ± 1.6^{b}
Survival (%)	45.4 ± 2.6^{b}	36.7 ± 1.5^{b}	47.2 ± 9.5^{ab}	59.7 ± 6.6^{a}
Extrapolated GFY (t/ha/yr)	0.87 ± 0.09^{a}	0.50 ± 0.07^{b}	0.76 ± 0.01^{ab}	0.44 ± 0.17^{b}
Extrapolated NFY (t/ha/yr)	0.85 ± 0.09^{a}	0.48 ± 0.07^{b}	0.73 ± 0.01^{ab}	0.42 ± 0.17^{b}
Common carp				
Parameters	Treatments			
	T_1	T_2	T_3	T_4
Initial mean weight (g/fish)	1.2 ± 0.2^{a}	1.1 ± 0.1^{a}	1.0 ± 0.1^{a}	1.2 ± 0.2^{a}
Initial total weight (g/100m^2)	26.0 ± 4.3^{a}	25.2 ± 2.2^{a}	23.2 ± 2.7^{a}	26.7 ± 4.0^{a}

Final mean weight (g/fish)	1062.8±357.2[a]	666.0±191.0[a]	1167.5±120.2[a]	584.9±183.0[a]
Final total weight (kg/100m^2)	5.9±2.3[b]	3.0±1.1[b]	10.8±1.2[a]	4.8±0.8[b]
DWG (g/fish/day)	5.1±1.7[a]	3.2±0.9[a]	5.6±0.6[a]	2.8±0.9[a]
TWG (kg/pond)	9.1±3.9[ab]	4.5±1.8[b]	15.8±1.6[a]	7.7±1.2[b]
Survival (%)	22.7±3.8[b]	18.4±2.6[b]	41.6±4.4[a]	41.4±7.0[a]
Extrapolated GFY (t/ha/yr)	1.02±0.41[b]	0.53±0.10[b]	1.88±0.21[a]	0.84±0.14[b]
Extrapolated NFY (t/ha/yr)	1.01±0.41[b]	0.52±0.20[b]	1.88±0.21[a]	0.83±0.14[b]
Rohu				
Initial mean weight (g/fish)	0.8±0.0[a]	0.8±0.0[a]	0.8±0.0[a]	0.7±0.1[a]
Initial total weight (g/100m^2)	28.0±0.3[a]	28.5±0.9[a]	31.3±0.7[a]	25.4±4.8[a]
Final mean weight (g/fish)	209.5±15.4[a]	198.9±18.1[a]	225.2±13.7[a]	207.1±13.9[a]
Final total weight (kg/100m^2)	5.2±0.5[a]	4.6±0.5[a]	5.2±1.0[a]	6.0±0.3[a]
DWG (g/fish/day)	1.0±0.1[a]	0.9±0.1[a]	0.7±0.1[a]	1.0±0.1[a]
TWG (kg/pond)	7.7±.4[a]	6.8±0.5[a]	7.5±1.4[a]	9.6±0.6[a]
Survival (%)	66.9±4.0[a]	63.9±11.0[a]	60.1±9.1[a]	77.8±2.1[a]
Extrapolated GFY (t/ha/yr)	0.91±0.09[a]	0.80±0.08[a]	0.90±0.17[a]	1.04±0.05[a]
Extrapolated NFY (t/ha/yr)	0.90±0.09[a]	0.79±0.08[a]	0.90±0.17[a]	1.03±0.05[a]
Mrigal				
Initial mean weight (g/fish)	2.1±0.1[a]	1.7±0.1[b]	1.6±0.1[b]	1.5±0.2[b]
Initial total weight (g/100m^2)	46.1±3.6[a]	39.1±3.2[a]	34.9±1.9[a]	32.8±4.0[a]
Final mean weight (g/fish)	145.3±20.6[a]	150.1±17.0[a]	154.8±21.4[a]	133.4±9.1[a]
Final total weight (kg/100m^2)	2.1±0.4[a]	2.1±0.7[a]	2.3±0.4[a]	2.4±0.3[a]
DWG (g/fish/day)	0.7±0.1[a]	0.7±0.1[a]	0.7±0.1[a]	0.6±0.0[a]
TWG (kg/pond)	3.0±0.6[a]	3.0±0.9[a]	3.3±0.6[a]	3.8±0.4[a]
Survival (%)	66.0±5.3[a]	58.1±16.1[a]	65.7±6.8[a]	78.9±5.1[a]
Extrapolated GFY (t/ha/yr)	0.38±0.08[a]	0.36±0.12[a]	0.40±0.07[a]	0.41±0.06[a]
Extrapolated NFY (t/ha/yr)	0.37±0.08[a]	0.36±0.12[a]	0.39±0.07[a]	0.41±0.06[a]
NFY carp only (t/ha/yr)	4.36±0.47[ab]	3.51±0.42[b]	5.45±0.45[a]	4.15±0.40[ab]
NFY of SIS only (t/ha/yr)	-	0.21±0.07[a]	0.05±0.02[b]	0.05±0.02[b]
Combined NFY (t/ha/yr)	4.36±0.47[ab]	3.72±0.36[b]	5.52±0.43[a]	4.20±0.41[ab]
Feed conversion ratio (FCR)	2.44±0.30[a]	2.44±0.21[a]	1.02±0.06[b]	-

Gross margin was highest for T_3, which was significantly higher than T_1 and T_2 (Table 4). Margins varied from 460 to 966 NRs per pond, and reduced or no feeding provided the highest margins.

Table 4. Gross margin analysis of different treatments (in 1,000 NRs/100 m^2 pond).

Variables	Treatment			
	T_1	T_2	T_3	T_4
Carp seed	498.2±4.3^a	501.6±2.6^a	502.7±3.1^a	498.7±3.0^a
SIS seed		49.9±0.4^a	50.2±0.2^a	49.5±0.2^a
Bleaching	350	350	350	350
Urea	338.4	338.4	338.4	338.4
DAP	364	364	364	364
Bamboo			250	250
Tray	70	70	70	
Feed	1627.1±166.1^a	1382.2±7.0^a	871.5±47.5^b	
Total variable cost	3247.7±165.8^a	3056.0±9.9^a	2796.8±46.7^b	1850.6±3.2^c
Return				
Carp	6440.3±680.3^{ab}	5200.6±612.6^b	8031.1±631.2^a	6135.9±574.3^{ab}
SIS		509.5±100.9^a	323.7±45.4^a	382.7±29.2^{ab}
Gross return	6440.3±680.3^{ab}	5710.0±525.2^b	8354.7±612.9^a	6518.6±563.1^{ab}
Gross margin	3192.6±622.4^{bc}	2654.0±519.9^c	5557.9±588.4^a	4618.5±566.0^{ab}
Gross margin (1,000 NRs/ha/yr)	554.9±108.2^{bc}	461.3±90.4^c	966.0±102.3^a	802.7±98.4^{ab}

DISCUSSION

Adding bamboo substrate to ponds affected the growth and production of grass carp and common carp. Mean harvest weight and DWG of grass carp in T_4 was significantly lower, corresponding to higher survival that caused increased competition for food. Since much of the experimental duration (four months) was in winter, grass was fed at 50% body weight of grass carp, which might be low and cause them to shift to supplemental feed. Better survival of grass carp in substrate ponds was perhaps due to shelter and cover provided by bamboo substrate. Similar to grass carp, survival of common carp was significantly higher ($P<0.05$) in ponds with bamboo substrate (T_3 and T_4) than in ponds without substrate (T_1 and T_2). Higher survival along with availability of periphyton and supplemental feed resulted in higher GFY and NFY for common carp in T_3, indicating that common carp required both supplemental feed and periphyton (Rai et al. 2012) for better growth and production.

Production of SIS was better in fed ponds than in periphyton substrate ponds. Contribution of SIS to total fish production in T_2 was 9.3±2.3%, significantly higher than in T_3 (3.47±0.6%) and similar to results from Gupta (2011) (3.8%–12.6% of total production). SIS was harvested seven times during monthly sampling. NFY of carp in T_3 was significantly higher than in T_2, with no significant differences among other treatments. This demonstrated that yield of carp was enhanced by adding substrate and reducing feed input by 50%. Combined NFY was significantly higher in T_3 than that of T_2, again indicating that periphyton-based culture system produced better yield than conventional carp-SIS polyculture. The overall results showed that periphyton had a positive effect on survival, growth, and production of carp (Azim et al. 2002, Rai et al. 2008).

Feed constituted 45%–50% of total variable cost for carp polyculture, while it was only 31% for periphyton-based polyculture. It is possible this cost could be lowered further with increased substrate area (Azim et al. 2004) and fertilization. Due to lack of feed cost, total variable cost of T_4 (NRs 1850.6±3.2 per 100 m^2) was significantly lower ($P<0.05$) than fed treatments. Similarly, feed cost of T_3 (NRs 871.5±47.5 per 100 m^2) was significantly lower ($P<0.05$) than other treatments with supplemental feeding. Periphyton along with 50% supplemental feed also improved FCR significantly ($p<0.05$) in T_3 (1.02±0.06).

CONCLUSION

Adding bamboo substrate for periphyton production with 50% supplementary feed in a carp-SIS polyculture system enhanced fish production and lowered production cost. Farmers can earn income through carp sales and improve family health and nutrition through consumption of SIS from their ponds. This technology is suitable to rural farmers, as it is cost-effective, simple, and supports family nutrition. Since almost half of the experimental period was in winter, which probably reduced growth and survival of carp, it would be useful to run another trial to verify present findings.

ANTICIPATED BENEFITS

Adding periphyton and reducing feeding rate of carps produced a 74% increase in gross margin for carp polyculture systems. This low-cost technology for small-scale farmers fulfils both the household need of income generation and nutrition. In addition, the substrate provided shelter and cover to protect fish from predators like birds and also hindered poaching. Using substrate and SIS alone, without feed, was much more profitable than traditional farming with 100% feed application. These manipulations can be used by farmers to increase profit and food available without added inputs and with minimal training.

ACKNOWLEDGMENTS

We are thankful to Ganesh Malla who assisted in pond preparation, fish sampling, and harvesting. We also like recognizing contributions from all staff at the Aquaculture and Fisheries Department, AFU, who helped conduct the experiment.

LITERATURE CITED

APHA. 1980. Standard Methods for the Examination of Water and Wastewater. 15th edition. American Public Health Association, American Water Work Association and Water Pollution Control Federation, Washington, D.C., USA.

Azim, M.E., M.C.J. Verdegem, M.N. Rahman, M.A. Wahab, A.A. van Dam, and M.C.M. Beveridge. 2002. Evaluation of polyculture of Indian major carps in periphyton-based ponds. Aquaculture 213: 131–149.

Azim, M.E., M.A. Wahab, P.K. Biswas, T. Asaeda, T. Fujino, and M.C.J. Verdegem. 2004. The effect of periphyton substrate density on production in freshwater polyculture ponds. Aquaculture 232: 441–453.

Azim, M.E., M.A. Wahab, A.A. van Dam, M.C.M. Beveridge, A. Milstein, and M.C.J. Verdegem. 2001. Optimization of fertilization rate for maximizing periphyton production on artificial substrates and the implications for periphyton-based aquaculture. Aquaculture Research 32: 749–760.

Bhujel, R.C. 2009. Increasing role and potential of small-scale aquaculture: National and regional perspectives. Symposium on small-scale aquiculture for increasing resilience of rural livelihoods in Nepal. Kathmandu, Nepal.

Diana, J.S. 2012. Is lower intensity aquaculture a valuable means of producing food? An evaluation of its effect on near-shore and inland waters. Reviews in Aquaculture 4: 234–245.

Gupta, M.C. 2011. Comparison of performance of Dedhuwa (*Esomus danricus*), Mara (*Amblypharyngodon mola*) and Pothi (*Puntius sophore*) in carp-Prawn polyculture ponds in Chitwan, Nepal. Master of Science Thesis, Tribhuwan University, IAAS, Rampur, Chitwan, Nepal.

Rai, S., and Y. Yi. 2012. Nibbling frequency of carps in fed and non-fed periphyton-based aquaculture system. The Israeli Journal of Aquaculture 64: 818–822.

Rai, S., S.H. Thilsted, M.K. Shrestha, M.A. Wahab, and K. Gharti. 2012. Improvement of women's livelihoods, income, and nutrition through carp-SIS-Prawn polyculture in Terai, Nepal. Asian Fisheries Science. Special Issue 25S: 217–225.

Rai, S., Y. Yi, M.A. Wahab, A.N. Bart, and J.S. Diana. 2010. Comparison of the growth and production of carp in polyculture ponds with supplemental feeding using rice straw and kanchi as substrates. Our Nature 8: 92–105.

Rai, S., Y. Yi, M.A. Wahab, A.N. Bart, and J.S. Diana. 2008. Comparison of rice straw and bamboo stick substrates in periphyton-based carp polyculture systems. Aquaculture Research 39: 464–473.

Roos, H., M.M. Islam, and S.H. Thilsted. 2003. Small fish is an important dietary source of vitamin A and calcium in rural Bangladesh. International Journal of Food Science and Nutrition 54: 329–339.

Roos, N., M.A. Wahab, C. Chamman, and S.H. Thilsted. 2006. Understanding the links between agriculture and health. 2020 vision for Food, Agriculture and Environment. International Food Policy Research, Washington, D.C. USA Focus: 44–49.

UNICEF. 2012. A milestone plan launched to improve maternal and child nutrition in Nepal. http://www.unicef.org/Nepal/5476_7891.htm. Accessed 13 January 2014.