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Comparison of the Growth and Production of Carps in Polyculture Ponds with Supplemental Feed using Rice Straw and Kanchi as Substrates

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Abstract

An experiment was carried to compare the performance of rice straw and kanchi in carp polyculture ponds with supplemental feed. The experiment included two treatments in triplicates: a) rice straw substrate (3x625 kg•ha^{-1}) with supplemental feeding and b) kanchi substrate (390 kanchi•pond^{-1}) with supplemental feeding. Fingerlings (n=40) of rohu, *Labeo rohita* (23.3±0.5 g), catla, *Catla catla* (26.0±0.6 g), mrigal, *Cirrhinus mrigala* (25.4±0.7 g), common carp, *Cyprinus carpio* (28.5±1.9 g) and silver carp, *Hypophthalmychthys molitrix* (32.1±1.3 g) were stocked at 3:2:2:2:1 ratio. Fish growth and weight gains did not vary between the rice straw and the kanchi treatment except in catla (P>0.05). Daily and total weight gains of catla was 48 and 32% higher in the kanchi treatment than in the rice straw treatment (P<0.05). However, the rice straw treatment gave more profit than the kanchi treatment. Based on fish production and gross margin, the rice straw treatment seems better for resource-poor farmers.

***Key words*:** Rice straw, Kanchi, substrate, supplemental feed, carp polyculture

Introduction

Substrates added to the ponds indeed increased fish production substantially (Hem and Avit, 1994; Ramesh *et al.*, 1999; Wahab *et al*., 1999; Keshavnath *et al*., 2001; Azim *et al*., 2002a; Mridula *et al*., 2003). It is estimated that potential fish production from periphyton-based pond aquaculture systems is around 5 tonnes•ha^{-1}•y^{-1} (Azim *et al*., 2001b; Van Dam *et al*., 2002). However, in most cases fish production obtained from periphyton-based aquaculture system is less than the predicted production, and only a few trials (Azim *et al*., 2001a; Azim *et al*., 2002a; 2002b) could achieve this fish production level. Van Dam *et al.* (2002) have suggested that there are three ways to increase fish production in the periphyton-based aquaculture systems: manipulating nutrient levels, using substrates that facilitate periphyton growth, and increasing the surface area index. Since increasing density of bamboo poles beyond a certain level does not increase fish production (Keshavnath *et al.*, 2002; Azim *et al*., 2004), it is not economically feasible to increase substrate density further. Thus, manipulating nutrient levels and using substrates that facilitate periphyton growth seem to be possible solution to enhance fish production in periphyton-based pond aquaqculture system.

In semi-intensive systems, artificial feed benefits the ponds in two ways either through direct consumption by cultured fish or indirect supply of nutrients from decomposition by benthos, fungi and protozoa (Moriarty, 1986; Milstein, 1992; Moriarty, 1997). In pond culture, on average about 21% of nitrogen and 19% of phosphorous in the artificial feed are retained by the fish (Siddiqui and Al-Harbi, 1999), while 14% of nitrogen and 21% of phosphorous are used by phytoplankton (Neori and Krom, 1991) and the remaining nitrogen and phosphorous mainly stimulate bacteria, fungi and protozoa production, which in turn may be consumed by zooplankton (Tang, 1970; Langis *et al*., 1988). Since bamboo is expensive to resource-poor farmers, rice straw and kanchi can be alternatives to bamboo. Previous studies on rice straw (Ramesh *et al*., 1999; Mridula *et al*., 2003; Mridula *et al*., 2005) and kanchi (Wahab *et al*., 1999; Azim *et al*., 2002a) as substrates in non-fed ponds have showed that both substrates are capable to enhance fish production. There is a need to compare the performance of rice straw and kanchi in carp polyculture ponds with supplemental feed.

The objective of the experiment was to compare the effect of rice straw and kanchi on water quality, plankton, periphyton, benthos, bacteria, carp growth and production, and economic returns in carp polyculture ponds supplemented with on-farm feed.

Materials and methods

An experiment was conducted in six 40 m^{-2} (8×5 m) ponds of 1.5 m deep at Field Laboratory of Fisheries Faculty, Bangladesh Agricultural University at Mymensingh, Bangladesh for 90 days during February to May 2006. The experiment included two treatments in triplicates each: a) rice straw substrate (3 straw mats per pond, 3×625 kg•ha^{-1}) with supplemental feed (rice straw treatment) and b) kanchi substrate (390 kanchi per pond) with supplemental feed (kanchi treatment). The treatments were allocated to the experimental ponds randomly.

Prior to placing the substrates, all ponds were drained and dried for 10 days. The ponds were limed with CaO at a rate of 250 kg•ha^{-1}. Three days later the ponds were filled to 0.30 m deep. Afterwards, 390 kanchi (1.5 cm in diameter and 1.8 m in length) and three rice straw mats (2×1 m) were fixed in each of the kanchi and rice straw treatment ponds, respectively. Rice straw mats were prepared by pressing rice straw bundles between bamboo splits. Then, all ponds were filled to 1.10 m deep. Following day, ponds were fertilized with urea, triple superphosphate (TSP) and cow dung at rates of 31 kg•ha^{-1}, 16 kg•ha^{-1} and 1,250 kg•ha^{-1}, respectively, at fortnight basis. Dissolved oxygen (DO) in the rice straw ponds was monitored for two weeks until it reached the level higher than 2.2 mg•L^{-1} in the ponds. Then, fingerlings of rohu (23.3±0.5 g), mrigal (25.4±0.7 g), catla (26.0±0.6 g), silver carp (32.1±1.3 g) and common carp (28.5±1.9 g) were stocked at a species ratio of 3:2:2:2:1 and a density of 1 fish•m^{-2}. Supplementary feed made of rice bran and mustard oil cake (60:40) was given to fish. The feeding rate was kept at 3% of the body weight.

Dissolved oxygen, temperature and pH were measured weekly at 0600, 1800 and 0600 h of next day using a YSI model 58 oxygen meter (Yellow Springs Instruments, Yellow Springs, OH, USA) and a pH meter (HANA Microelectronics Public Co. Ltd., Bangkok, Thailand). DO concentrations were measured at three depths, 10 cm, 50 cm and 70 cm below water surface. Secchi disc depth was monitored weekly at 0900 h. Composite column water samples were collected monthly at 0900-1000 h from three locations of each pond to analyse total alkalinity, total ammonia nitrogen (TAN), nitrite-nitrogen, soluble reactive phosphorus (SRP), total phosphorus (TP), chlorophyll-*a*, total suspended solids (TSS) and total volatile solids (TVS) following APHA (1980) and total nitrogen (TN) following Raveh and Avnimelech (1979).

Composite column water samples were also collected monthly for the analyses of planktons. A 5-L of sampled water was passed through plankton net with mesh size of 25 µm to make a concentrated volume of 50 mL. The concentrated samples were preserved in small plastic bottles containing 6% formalin. Planktons were enumerated using a Sedgewick-Rafter counting cell (S-R cell) under a binocular microscope (Swift M-4000, Swift Instrument Inc.). Plankton concentrations were estimated using the following formula: $N= (P\times C\times 100)/L$. where, N= the number of plankton units per litre of original pond water; P= the number of planktons counted in ten random fields of S-R cell; C= the volume of final concentrated sample (mL); L= the volume (L) of the pond water sample.

Pieces of rice straw was cut by scissors from three different depths (surface, middle and bottom) of each mat from each replication, and wrapped in an aluminum foil for monthly periphyton analysis. Each sample was transferred to an Erlenmeyer flask containing 50- mL distilled water and shaken in a mechanical shaker for 3 hours to detach periphytons from the straw surface. After removing periphytons from straw, the straw was dried overnight in an oven at 80°C to get the dry weight. For taxonomic identification, samples were preserved in 6% formalin. Periphytons were counted using a S-R cell under a binocular microscope. The number of periphyton units was estimated by using following formula: $N= (P\times C\times 100)/W$. where, N= Number of periphyton units; P= Number of periphyton units counted in ten random fields of S-R cell; C= Volume of final concentrated sample (mL); W= Weight of rice straw (g)

Periphyton taxa were identified to genus level by using keys from Ward and Whipple (1959), Wetzel (1983) and Bellinger (1992).

Dry matter of periphytons was estimated by filtering samples through pre-weighed and oven-dried GF/C filter papers and drying for 24 hours in an oven at 105°C. It was further combusted in a Muffle furnace at 550°C for 30 min to get ash content (%). Chlorophyll-*a* concentration was determined following the standard methods (APHA 1980). Periphytons from kanchi were analysed following Azim *et al*. (2002a).

Pieces of rice straw was cut from three different depths of each mat, pooled and kept in a sterilized tube containing phosphate buffer solution for bacteria analysis. Samples from the kanchi were collected by scrapping 2×2 cm^2 area by scalpel, and kept in a sterilized tube containing phosphate buffer solution. The samples were preserved in a refrigerator at 4°C. Total plate counting of the bacteria was done following APHA (1980). Periphyton number, biomass and bacteria total plate count were estimated based on the pond area for comparison between treatments.

Zoobenthic samples from the bottom of each pond were collected monthly by using an Ekman dredge (15×15 cm). The mud samples were collected from three random locations. The content of the dredge was sieved through a sieve of 250 µm mesh size. Zoobenthos were separated and preserved in 10% formalin. Zoobenthos were identified under a dissecting microscope (CH40RF200 Model, Olympus, Japan) following keys from Ward and Whipple (1959) and Needham and Needham (1962). Zoobenthos number was estimated following Rahman *et al.* (2006).

$N= (Y×10,000)/3A$. Where, N= number of benthic organisms per square meter (individuals•m^{-2}); Y= total number of benthic organisms counted in 3 samples; A= area of Ekman dredge (cm^2).

At least 30% of each stocked fish species were sampled monthly and weighed individually using an electronic scale to determine fish growth and adjust amount of feed. At the end, substrates were removed from the ponds, and fish were harvested, counted and weighed individually. Weight gains and survival rates were calculated.

Gross margin analysis was carried out to compare economic returns between treatments. The prices of all inputs and outputs were based on the local market price at Mymensingh. The analysis excluded labour cost as rural farmers use family labours to get farm work done. Expectant life of bamboo and kanchi was assumed to be 3, and 1 and half years, respectively.

Data were statistically analyzed by Student's t-test using SPSS (version 12.0) statistical software (SPSS Inc., Chicago, USA). Differences were considered significant at an alpha level of 0.05 ($p<0.05$). All means were given with ±1 standard error (S.E.).

Result

There were no significant differences in the water quality parameters between treatments except DO concentration ($P>0.05$, Tab. 1). DO concentration at 0600 h was significantly lower at three depths in the rice straw treatment than that in the kanchi treatment ($P<0.05$), while DO concentration at 1800 h was significantly lower only at 10 cm below water surface in the rice straw treatment than that in the kanchi treatment ($P<0.05$).

Phytoplankton and zooplankton densities in pond water did not differ between treatments ($P>0.05$, Tab. 2-3). Density of zoobenthos in the pond sediment was 512±165 individual•m^{-2} in the rice straw and 280±34 individual•m^{-2} in the kanchi treatments, which were not significantly different (P>0.05).

Periphyton densities didn't differ significantly between treatments (P>0.05, Tab. 4). Dry matter, ash, ash free dry matter and chlorophyll-a concentration of periphytons did not differ significantly between treatments (P>0.05, Tab. 5). Bacteria total plate count was 65,460±11,620 (×10^6 cfu•m^{-2}) in the rice straw, which was higher than that of 13,035±1,202 (×10^6 cfu•m^{-2}) in the kanchi (P<0.05).

There were no significant differences in fish growth and production except catla between the rice straw and kanchi treatments (P>0.05, Tab. 6). Daily and total weight gains of catla were higher in the kanchi treatment than in the rice straw treatment (P<0.05). Combined total weight gain was also did not differ between the rice straw and kanchi treatment (P>0.05). Silver carp (24-32%) and rohu (23-27%) were the major contributors to combined total weight gain in all three treatments while mrigal, common carp and catla contributed 16-22%, 11-20% and 12-15% respectively (Fig. 1). There were no differences in survival rates of rohu, catla, mrigal, common carp and silver carp among all treatments (P>0.05). Overall FCR didn't differ between the rice straw and kanchi treatments (P>0.05).

Gross margin analysis showed that gross return was significantly higher in the kanchi treatment than in the rice straw treatment (P<0.05; Tab. 7). In contrast, gross margin was higher in the rice straw treatment than in the kanchi treatment.

Discussion

All water quality parameters remained in the normal range for carp culture. There were no significant effects of substrates on water quality except on dissolved oxygen. Low dissolved oxygen concentration in the rice straw treatment was probably due to increased biological oxygen demand (Dharmaraj *et al*., 2002) which is common in the water with predominate heterotrophic food production (Moriarity, 1997).

Adding substrate to the fed ponds did not affect densities of plankton and zoobenthos significantly in the present experiment. Plankton abundance in pond water showed the fertile state of the ponds in all treatments. Abundance of zoobenthos was in agreement with the result reported by Habib *et al*. (1984) in BAU ponds. Periphyton density and biomass did not differ between rice straw and kanchi, indicating that both substrates were equally preferred by periphytons. Contrast to periphytons, bacteria preferred rice straw over kanchi. Higher bacteria total plate count on the rice straw was perhaps due to the provision of more organic matter and surface area for bacterial growth (Schroeder, 1978; Van Dam *et al*., 2002).

Fish growth and production did not vary between the rice straw and kanchi treatments except catla, indicating that both substrates favour growth and production of carps. Growth rate was higher than 1.2 g•$fish^{-1}$•day^{-1} in all species in both treatments, except in catla in the rice straw treatment. Lower daily and total weight gains of catla in the rice straw treatment than in the kanchi treatment could be attributed to relatively lower zooplankton population in the rice straw ponds with supplemental feed. Catla is predominantly zooplankton feeder (Chakrabarti, 1998). In

Table 1. Summary of water quality parameters in the rice straw and kanchi treatments (Mean±S.E.)

Parameter	Rice straw	Kanchi
Temperature at 0600 h (^{0}C)	25.8±1.0	26.3±0.0
Temperature at 1800 h (^{0}C)	29.4±0.0	29.4±0.1
DO at 0600 h (mg•L^{-1})		
10 cm	3.8±0.1^b	5.0±0.1^a
50 cm	3.2±0.1^b	4.2±0.1^a
70 cm	2.8±0.1^b	3.7±0.1^a
DO at 1800 h (mg•L^{-1})		
10 cm	7.5±0.2^b	9.2±0.1^a
50 cm	6.62±1.0	7.5±0.2
70 cm	4.7±0.3	5.6±.0.3
pH at 0600 h	8.4±0.0	8.4±0.0
pH at 1800 h	8.8±0.0	8.8±0.0
Secchi disk depth (cm)	24.3±0.8	21.53±0.8
Total alkalinity (mg•L^{-1} as $CaCO_3$)	125±5	143±7
Chlorophyll-a (ug•L^{-1})	50±11	61±13
Total nitrogen (mg•L^{-1})	1.45±0.27	1.42±0.17
Total ammonium nitrogen (mg•L^{-1})	0.10±0.01	0.15±0.03
Nitrite nitrogen (mg•L^{-1})	0.01±0.00	0.01±0.01
Total phosphorous (mg•L^{-1})	1.94±0.05	2.16±0.37
Soluble reactive phosphorous (mg•L^{-1})	0.90±0.16	0.87±0.28
Total suspended solids (mg•L^{-1})	75±1	74±9
Total volatile solids (mg•L^{-1})	46±3	44±8

Mean values with different superscript letters in the same row are significantly different ($P<0.05$).

Table 2. Abundance of phytoplankton (units•L^{-1}) in the pond water in the rice straw and kanchi treatments (Mean±SE)

Group	Genus	Rice straw	Kanchi
Bacillariophyceae	*Coscinodiscus*	2,302±831	2,062±387
	Cyclotella	10,135±6,131	55,998±49,845
	Diatoma	667±406	450±158
	Fragillaria	3,202±946	2,255±1,780
	Gomphonema	370±186	903±423
	Gyrosigma	0±0	85±85
	Melosira	3,458±648	6,183±3,221
	Navicula	3,043±1,749	1,608±394
	Nitzschia	5,818±2,068	2,775±1,003
	Pinnularia	0±0	0±0
	Surirella	975±333	860±206
	Synedra	4,575±3,718	823±192
	Tabellaria	872±757	542±85
	Subtotal	35,417±4,600	74,548±46,077
Chlorophyceae	*Actinastrum*	572±72	392±173
	Ankistrodesmus	322±161	418±215
	Centritractus	0±0	167±167

Contd....

Table 2-Contd....

	Chlamydomonas	412±217	255±3
	Characium	0±0	0±0
	Chlorella	8,933±2,807	14,748±1,262
	Chodatella	42±42	90±90
	Coelastrum	0±0	1,433±1,192
	Cosmarium	45±45	0±0
	Crucigenia	4,267±1,592	5,152±2,034
	Gonatozygon	95±95	487±177
	Microspora	177±177	587±463
	Mougeotia	3,662±1,690	7,738±1,665
	Oedogonium	0±0	85±85
	Oocystis	4,850±488	3,648±705
	Pediastrum	2,617±1,634	4,063±1,805
	Scenedesmus	8,287±2,237	11,858±1,830
	Selenastrum	625±317	152±77
	Sphaerocystis	2,043±732	9,602±5,677
	Staurastrum	78±78	237±237
	Tetraspora	737±186	777±420
	Tetraedron	615±315	575±163
	Treubaria	157±157	157±157
	Ulothrix	357±229	933±933
	Volvox	167±84	83±83
	Subtotal	45,625±8,535	57,830±3,475
Cyanophyceae	*Anabaena*	168±85	212±149
	Aphanocapsa	78±78	0±0
	Chroococcus	1,537±755	2,595±460
	Gloecapsa	1,513±573	463±247
	Gomphosphaeria	823±147	535±283
	Merismopedia	0±0	160±160
	Microcystis	420±289	467±154
	Oscillatoria	1,642±1,066	348±176
	Subtotal	6,182±1,469	4,780±697
Euglenophyceae	*Euglena*	41,170±13,606	109,355±70,951
	Phacus	1,163±144	1,122±286
	Trachelomonas	800±113	1,245±530
	Subtotal	43,133±13359	111,722±71,165
Total phytoplankton		130,357±16,683	248,880±114,423
Identified genus (no.)		42	45

Table 3. Abundance of zooplankton (units•L^{-1}) in the pond water in the rice straw and kanchi treatments (Mean±SE).

Group	Genus	Rice straw	Kanchi
Sarcodina	*Difflugia*	715±271	915±369
Rotifera	*Asplanchna*	902±42	828±225
	Brachionus	1,872±341	2,142±597
	Filinia	140±71	580±300
	Keratella	693±250	572±188
	Lecane	227±129	567±289
	Monostyla	0±0	140±140
	Polyarthra	1,453±619	1,237±395
	Trichocerca	473±125	587±308
	Subtotal	5,760±922	6,652±1553
Crustacea	*Cyclops*	842±164	935±349
	Diaptomus	290±75	152±152
	Ceriodaphnia	222±117	297±97
	Daphnia	150±150	142±71
	Diaphanosoma	157±157	0±0
	Moina	327±60	525±351
	Nauplius	1,530±153	1,535±311
	Subtotal	3,517±453	3,585±840
Total zooplankton		9,992±452	11,152±1253
Identified species (no.)		15	15

Table 4. Abundance of periphyton (10^3×units•m^{-2}) in the rice straw and kanchi treatments (Mean±SE)

Group	Genus	Rice straw	Kanchi
Bacillariophyceae	*Coscinodiscus*	1,068±1,068	868±459
	Cyclotella	2,426±445	3,471±1,138
	Cymbella	560±560	0±0
	Diatoma	16,221±8,258	20,476±10,326
	Fragillaria	43,367±9,405[a]	14,750±4,211[b]
	Gomphonema	9,585±1,679[a]	174±174[b]
	Melosira	12,258±984	6,073±4,002
	Navicula	37,309±8,922	74,096±23,699
	Nitzschia	80,142±25,592	55,182±22,538
	Surirella	513±513	0±0
	Synedra	33,539±4,440[a]	12,494±1,673[b]
	Tabellaria	5,492±2,859	1,735 ±459
	Subtotal	242,482±30,886	189,319±21,005
Chlorophyceae	*Actinastrum*	1,120±560	0±0
	Centritractus	560±560	174±174
	Characium	1,943±1,205	5,726±2,671

Contd....

Table 4-Contd....

	Chlorella	46,942±16,399	7,115±1,483
	Closterium	1,719±318	694±459
	Coelastrum	0±0	868±347
	Cosmarium	3,267±1,587	174±174
	Crucigenia	23,277±12,917	2,429±1,655
	Cylindrocapsa	0±0	14,229±3,623
	Gonatozygon	5,090±2,239	0±0
	Microspora	2,377±2,377	694±347
	Mougeotia	20,511±7,717	2,082±902
	Oedogonium	16,139±9,598	10,759±5,968
	Oocystis	1,531±149[b]	3,471±626[a]
	Pediastrum	7,556±2,828	1,388±626
	Scenedesmus	44,991±8,687	22,732±7,064
	Selenastrum	560±560	0±0
	Stigeoclonium	762±762[b]	180,469±46,057[a]
	Staurastrum	0±0	174±174
	Tetraspora	0±0	174±174
	Tetraedorn	1,120±560	347±174
	Triplocerus	3,658±2,047	0±0
	Ulothrix	1,480±933	0±0
	Subtotal	184,603±40,741	253,697±40,753
Cyanophyceae	*Chroococcus*	2,194±2,194	2,429±1,655
	Gloecapsa	0±0	4,685±1,562
	Gomphosphaeria	411±411	0±0
	Oscillatoria	10,633±3,422	10,932±10,161
	Phormidium	12,151±3,421	2,776±347
	Subtotal	25,389±3,837	20,823±9,097
Euglenophyceae	*Euglena*	10,113±146[a]	694±347[b]
	Phacus	560±560	0±0
	Trachelomonas	1,485±938	174±174
	Subtotal	12,158±1,162[a]	868±459[b]
Sarcodina	*Difflugia*	3,352±613	521±0
Rotifera	*Asplanchna*	1,528±765	1,041±601
	Brachionus	1,027±1,027	347±347
	Conochilus	822±822	1,735±966
	Lecane	762±762	521±301
	Monostyla	0±0	347±174
	Subtotal	4,139±903	3,991±1,215
Total Periphyton		472,123±71,506	469,218±31,646
Identified genus (no.)		43	40

Mean values with different superscript letters in the same row are significantly different (P<0.05).

Table 5. Periphyton biomass and pigment concentration in the rice straw and kanchi treatments (Mean±S.E.)

Parameter	Rice straw	Kanchi
Dry matter (g•pond^{-1})	634.4±14.4	803.9±163.7
Ash (%)	43.3±2.0	45.9±1.7
Ash Free Dry Matter (g•pond^{-1})	302.0±19.8	432.6±64.6
Chlorophyll-a (g•pond^{-1})	1.1±0.1	1.9±0.3

Table 6. Growth Performance of carps stocked in the rice straw and kanchi treatments (Mean±S.E.)

Parameter	Rice straw	Kanchi
Rohu		
Initial total weight (kg•pond^{-1})	0.28±0.01	0.28±0.01
Initial mean weight (g•fish^{-1})	23.10±0.47	23.53±1.21
Final total weight (kg•pond^{-1})	1.73±0.12	1.89±0.05
Final mean weight (g•fish^{-1})	150.30±4.09	162.07±8.85
Daily weight gain (g•fish^{-1}•day^{-1})	1.41±0.05	1.54±0.10
Total weight gain (kg•pond^{-1})	1.45±0.12	1.60±0.06
Survival (%)	100.0±0.0	100.0±0.0
Catla		
Initial total weight (kg•pond^{-1})	0.22±0.01	0.21±0.00
Initial mean weight (g•fish^{-1})	27.27±1.00	25.87±0.26
Final total weight (kg•pond^{-1})	0.91±0.04	1.12±0.06
Final mean weight (g•fish^{-1})	113.43±a5.33	153.40±14.03
Daily weight gain (g•fish^{-1}•day^{-1})	0.96±0.07^{b}	1.42±0.15^{a}
Total weight gain (kg•pond^{-1})	0.69±0.05^{b}	0.91±0.06^{a}
Survival (%)	100.0±0.0	91.7±4.2
Mrigal		
Initial total weight (kg•pond^{-1})	0.20±0.00	0.20±0.02
Initial mean weight (g•fish^{-1})	25.03±0.28	25.60±2.16
Final total weight (kg•pond^{-1})	1.03±0.05	1.31±0.09
Final mean weight (g•fish^{-1})	135.00±5.54	163.80±11.49
Daily weight gain (g•fish^{-1}•day^{-1})	1.22±0.06	1.54±0.12
Total weight gain (kg•pond^{-1})	0.83±0.05	1.11±0.09
Survival (%)	100.0±0.0	100.0±0.0
Common		
Initial total weight (kg•pond^{-1})	0.21±0.01	0.23±0.04
Initial mean weight (g•fish^{-1})	26.63±1.54	28.77±4.47
Final total weight (kg•pond^{-1})	1.25±0.08	1.16±0.13
Final mean weight (g•fish^{-1})	172.43±8.72	145.17±15.98
Daily weight gain (g•fish^{-1}•day^{-1})	1.62±0.09	1.29±0.22
Total weight gain (kg•pond^{-1})	1.04±0.07	0.93±0.16
Survival (%)	95.8±4.2	100.0±0.2
Silver		
Initial total weight (kg•pond^{-1})	0.13±0.00	0.13±0.01
Initial mean weight (g•fish^{-1})	31.70±0.91	32.00±3.08
Final total weight (kg•pond^{-1})	1.42±0.10	1.67±0.14
Final mean weight (g•fish^{-1})	387.73±24.47	417.37±34.93
Daily weight gain (g•fish^{-1}•day^{-1})	3.96±0.28	4.28±0.38
Total weight gain (kg•pond^{-1})	1.29±0.10	1.54±0.14
Survival (%)	100.0±0.0	100.0±0.0

Contd....

Table 6-Contd....

Combined		
Initial total weight (kg•pond^{-1})	1.04±0.02	1.05±0.04
Final total weight (kg•pond^{-1})	6.28±0.32	7.14±0.02
Total weight gain (kg•pond^{-1})	5.24±0.32	6.09±0.06
FCR	1.2±0.1	1.1±0.0

Mean values with different superscript letters in the same row are significantly different (P<0.05).

Table 7. Gross margin analysis of different treatments based on 40 m^2 pond in Bangladeshi currency Taka

Item	**Unit**	**Taka•unit^{-1}**	**Rice straw**		**Kanchi**	
			Quantity	Taka	Quantity	Taka
Gross return						
Rohu	kg	60	1.73	104±7	1.89	113±3
Catla	kg	60	0.91	54±3 [b]	1.12	67±3 [a]
Mrigal	kg	60	1.03	62±3	1.31	79±6
Common	kg	60	1.25	75±9	1.16	70±13
Silver	kg	60	1.42	85±10	1.67	100±15
Total gross return				381±31 [b]		429±2 [a]
Variable cost						
Fingerlings						
Rohu	Pcs	3.5	12	42	12	42
Catla	Pcs	3.5	8	28	8	28
Mrigal	Pcs	3.5	8	28	8	28
Common	Pcs	3.5	8	28	8	28
Silver	Pcs	3.5	4	14	4	14
Feed						
Rice bran	kg	10	4.1	41	4.8	48
Mustard oil cake	kg	15	3.0	45	3.1	47
Fertilizer						
Urea	kg	8	0.868	7	0.868	7
TSP	kg	15	0.448	7	0.448	7
Cowdung	kg	0.4	35	14	35	14
Lime	kg	12	1	12	1	12
Kanchi	Pcs	1	-	-	390 for 4 crops	98
Bamboo	Pcs	130	2 for 9 crops	29	-	-
Wire				20		
Interest on working capital		10%		8		9
Total variable cost				322±0		381±0
Gross margin				59±18		48±1

Mean values with different superscript letters in the same row are significantly different (P<0.05).

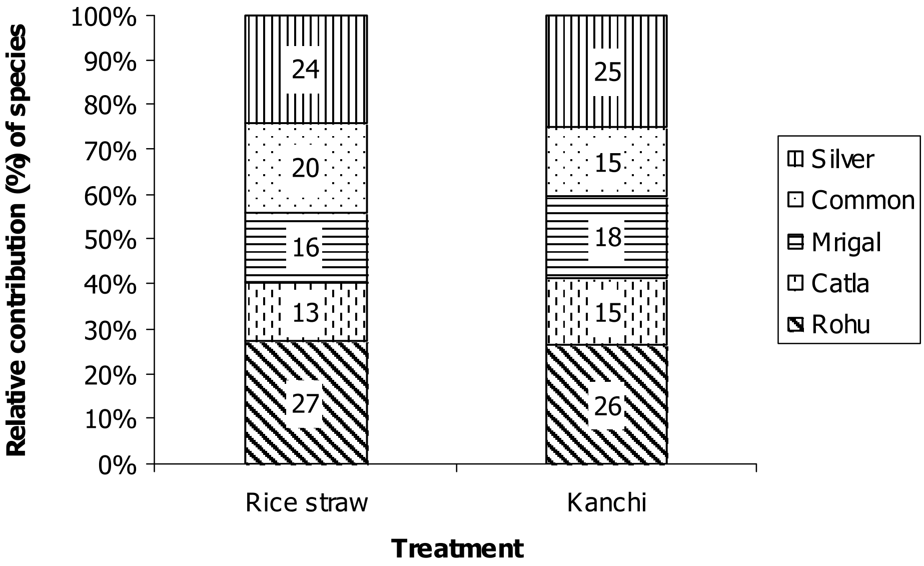

Figure 1. Relative contribution of different species on combined total weight gain in the rice straw and kanchi treatments.

the present experiment, combined total weight gains were higher than that reported by Azim *et al*. (2001b) and Van Dam *et al*. (2002) for the potential yield from periphyton-based aquaculture system. Among the stocked carps, silver carp contributed more than 24% of the total weight gain in both treatments, though it represented only 10% of the population in the present experiment. Silver carp grew better because it is an efficient filter feeder (Milstein *et al*., 1985). FCR did not differ between the rice straw and kanchi treatments because feed was provided based on fish biomass and fish production was not significantly different between the treatments. FCR in the present experiment was lower than that reported by Sahu *et al.* (2007).

Gross margin analysis showed that both treatments were profitable. Gross margin was higher in the rice straw treatment than that in the kanchi treatment due probably to low cost of rice straw. Since the rice straw in the ponds with supplemental feed gave fish production as high as in the kanchi ponds with supplemental feed, the rice straw treatment seemed better for the resource-poor farmers. As rice straw decomposes gradually, further research is needed on using rice straw as substrate for long term fish culture.

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References

APHA 1980. *Standard methods for the examination of water and wastewater*. 15th edn. American Public Health Association, Washington D.C.

Azim, M.E., M.A. Wahab, A.A. Van Dam, M.C.M. Beveridge, M.C.J. Verdegem and A.A. Van Dam 2001a. The potential of periphyton based culture of two Indian major carps, rohu, *Labeo rohita* (Hamilton) and gonia, *Labeo gonius* (Linnaeus). *Aquacul. Res.* ***32*****:** 209-216.

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

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.C.J. Verdegem, H. Khatun, M.A. Wahab, A.A. van Dam and M.C.M. Beveridge 2002b. A comparison of fertilization, feeding and three periphyton substrates for increasing fish production in freshwater pond aquaculture in Bangladesh. *Aquaculture* ***212*****:** 227-243

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

Bellinger, E.G. 1992. *A key to common algae*. The Institute of Water and Environmental Management, London.

Chakrabarty, N.M. 1998. *Biology, culture and production of Indian major* carp- *A review*. Narendra Publishing House, Delhi, India.

Dharmaraj, M., J.K. Manissery and P. Keshavnath 2002. Effects of a biodegradable substrate, sugarcane bagasse and supplementary feed on growth and production of fringe-lipped peninsular carp, *Labeo fimbriatus* (Bloch). *Acta Ichthyologica et Piscatoria* ***32*****:** 137-144.

Habib, A.B., M. Ahmed, M.A. Haque and A.K.M.A. Islam 1984. Status of macrobenthos in two ponds in Bangladesh Agricultural University Campus, Mymensingh. *Bangla. J. Agr. Sci.* ***11*****:** 39-46.

Hem, S. and J.L.B. Avit 1994. First results on 'acadja-enclos' as an extensive aquaculture system, Cote d'Ivoire (West Africa). *Bull. Maricul. Sci.* ***55*****:** 1040-1051.

Keshavnath, P., B. Ganghadhar, T.J. Ramesh, A.A. Van Dam, M.C.M. Beveredge and M.C.J. Verdegem 2002. The effect of periphyton and feeding on the production of the indigenous carps *Tor khudree* and *Labeo fimbratus*. *Aquaculture* ***213*****:** 207-218.

Keshavnath, P., B. Ganghadhar, T.J. Ramesh, A.A.Van Dam, M.C.M. Beveredge and M.C.J. Verdegem 2001. On farm evaluation of Indian major carp production with sugarcane bagasse as substrate for periphyton. *Asi. Fish. Sci.* ***14*****:** 367-376.

Langis, R., D. Proulx, J. de la Noue and P. Couture 1988. Effects of a bacterial biofilm on I Daphnia culture. *Aquacul. Engineer.* ***7*****:** 21-38.

Milstein, A. 1992. Ecological aspects of fish species interactions in polyculture ponds. *Hydrobiol.* ***231*****:** 17-186.

Milstein, A., B. Hepher and B. Teltsch 1985. Interactions between fish species and the ecological conditions in mono and polyculture pond system. *Aquacul. Fish. Manag.* ***16*****:** 305-317.

Moriarty, D.J.W. 1986. Bacterial productivity in ponds for culture of penaeid prawns. *Microbiol. Ecol.* ***12*****:** 259-270.

Moriarty, D.J.W. 1997. The role of microorganisms in aquaculture ponds. *Aquaculture* ***151*****:** 333-349.

Mridula, R.M., J.K. Manissary, P. Keshavnath, K.M. Shankar, M.C. Nandesha and K.M. Rajesh 2003. Water quality, biofilm production and growth of fringe-lipped carp (*Labeo fimbriatus*) in tanks provided with two solid substrates. *Aquaculture* ***87*****:** 263-267.

Mridula, R.M., J.K. Manissary, P. Keshavnath, K.M. Shankar, M.C. Nandesha and K.M. Rajesh 2005. Effects of paddy straw and sugarcane bagasse on water quality, bacterial biofilm production and growth and survival of rohu, *Labeo rohita* (Hamilton). *Aquacul. Res.* ***36*****:** 635-642.

Needham, J.G. and P.R. Needham 1962. *A guide to the study of fresh-water biology*. Holden-Day, Inc., San Francisco.

Neori, A. and M.D. Krom 1991. Nitrogen and phosphorous budgets in an intensive marine fishpond: the importance of microplankton. In *Nutritional Strategies and Aquaculture Waste* (Eds. C.V. Cowey and C.Y. Cho). pp. 223-230.

Rahman, M.M., M.C.J. Verdegem, L.A.J. Nagelkerke, M.A. Wahab, A. Milstein and J.A.J. Verreth 2006. Growth production and food preference of rohu *Labeo rohita* (H) in monoculture and in polyculture with common carp *Cyprinus carpio* (L.) under fed and non-fed ponds. *Aquaculture* ***257*****:** 359-372.

Ramesh, M.R., K.M. Shankar, C.V. Mohan and T.J. Varghese 1999. Comparison of three plant substrates for enhancing carp growth through bacterial biofilm. *Aquacul. Engineer.* ***19*****:** 119-131.

Raveh, A. and Y. Avnimelech 1979. Total nitrogen analysis in water, soil and plant material with persulfate digestion. *Wat. Res.* ***13*****:** 911-912

Sahu, P.K., J.K. Jena, P.C. Das, S. Mondal and R. Das 2007. Production performance of *Labeo calbasu* (Hamilton) in polyculture with three Indian major carps *Catla catla* (Hamilton), *Labeo rohita* (Hamilton) and *Cirrhinus mrigala* (Hamilton) with provision of fertilizers, feed and periphytic substrate as varied inputs. *Aquaculture* ***262*****:** 333-339.

Schroeder, G.L. 1978. Autotrophic and heterotrophic production of micro-organisms in intensely-manured fish ponds, and related fish yields. *Aquaculture* ***14*****:** 303-325.

Siddiqui, A.Q. and A.H. Al-Harbi 1999. Nutrients budgets in tanks with different stocking densities of hybrid tilapia. *Aquaculture* ***170*****:** 245-252.

Tang, Y.A. 1970. Evaluation of balance between fishes and available fish foods in multispecies fish culture ponds in Taiwan. *Trans Amer. Fish Soc.* ***4*****:** 708-718.

Van Dam, A.A., M.C.M. Beveridge, M.E. Azim and M.C.J. Vedegem 2002. The potential of fish production based on periphyton. *Rev. Fish Biol. Fisheries* ***12*****:** 1-31.

Wahab, M.A., Z.F. Ahmed, M.A. Islam, M.S. Haq and S.M. Ramatullah 1999. Effects of introduction common carp, Cyprinus carpio (L.) on pond ecology and growth of fish in polyculture. *Aquacul. Res.* ***26*****:** 619-628.

Ward, H.B. and G.C. Whipple 1959. *Freshwater Biology*. John Willey and sons Inc., New york.

Wetzel, R.G. 1983. Attached algal-substrata interactions; fact or myth, and when and how? In *Periphyton of freshwater ecosystems* (Ed. R.G. Wetzel), Dr. W. Junk publishers, The Hague. pp. 207-215.