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Growth performance of rohu, *Labeo rohita* (Ham.) in tanks provided with different levels of sugarcane bagasse as periphyton substrate

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ABSTRACT

Provision of biodegradable substrates in culture systems results in the production of biofilm/periphyton which serves as an additional natural food source for cultured fish. The effect of sugarcane bagasse on water quality, growth performance and production of the Indian major carp, rohu (*Labeo rohita*) was investigated through a 180 days experiment, by providing it at levels of 0, 1.5, 2.0, 2.5 and 3.0 t ha^{-1} and designating the treatments as T0, T1, T2, T3, T4 respectively. Dried cattle dung was applied initially to each tank @ 5.0 t ha^{-1}, followed by fortnightly doses of 1.0 t ha^{-1}. Bagasse did not adversely affect water quality. Only minor differences in periphyton and plankton biomass were observed between treatments. Survival of fish did not differ ($p>0.05$) among treatments. The substrate affected fish growth and production significantly ($p<0.05$) at all the densities tested. Fish production of 3456 g per 25 m^2 was obtained in the control (T0) without periphyton. In T1, T2, T3 and T4 treatments, yield increased by 68, 129, 123 and 119% respectively. The results demonstrated that sugarcane bagasse can be applied in pond bottom as a substrate at a density of 2.0 t ha^{-1} for increasing the production of rohu.

Keywords: Bagasse, Growth, Periphyton, Rohu, Substrate

Introduction

Asian aquaculture is dominated by semi-intensive systems of freshwater pond culture. In these systems, natural productivity is enhanced using fertilizers and the fish are provided with supplemental feeds. On an average, 5 to 15% of the nutrient input from fertilizers ends up in harvestable products (Schroeder *et al*., 1990; Edwards, 1993). Only about 15 to 30% of the nutrient input in feed-driven pond systems is converted into harvestable products (Acosta Nassar *et al*., 1994; Gross *et al*., 2000); the remainder is lost to the sediment, effluent and the atmosphere (Beveridge *et al*., 1994). Substrate-based fish culture is a viable option to make semi-intensive aquaculture systems more nutrient efficient, since periphyton is effectively utilised by many fish species which thrive low in the food chain.

Recent studies show that biodegradable substrates result in enhanced growth of fish/prawn in freshwater as well as brackishwater ponds (Keshavanath *et al*., 2004; Jana *et al*., 2006; Garg *et al*., 2007; Amish *et al*., 2008; Uddin *et al*., 2009; Asaduzzaman *et al*., 2010). Sugarcane bagasse was evaluated to be one of the good periphyton substrates in terms of periphytic ash-free dry matter, chlorophyll-*a* and nutrient composition (Gangadhar and Keshavanath, 2008). An earlier on-farm polyculture experiment with catla, rohu and common carp using sugarcane bagasse bundles hung in ponds revealed that maximum total fish production could be achieved at bagasse densities of 2.1 t ha^{-1} (117 bundles per 100 m^2) without feeding (Keshavanath *et al*., 2001). Considering the practical problems in making bundles of sugarcane bagasse and hanging them in ponds, the present study was aimed at evaluating the efficacy of sugarcane bagasse as a substrate when applied to the tank bottom. Rohu, one of the Indian major carps, was used as the test species since it is the most preferred species in carp polyculture and is known to utilise periphyton effectively (Azim *et al*., 2001a).

Materials and methods

Experimental setup

This experiment of 180 days duration was carried out in 5 cm thick mud-bottomed outdoor cement tanks (5 x 5 x 1 m) in the farm of Krishi Vigyan Kendra, Belgaum. The fresh sugarcane bagasse procured was soaked in water for 2 days to get rid of the sugar present and was then sun dried. Water from a nearby well was filled in the tanks, maintaining a level of 90 $\pm$ 5 cm; the evaporation loss was compensated through weekly pumping of water. Dried cattle dung was applied to each tank @ 5000 kg ha^{-1}. Bagasse was applied uniformly to three tanks randomly at 0 (control), 1.5, 2.0, 2.5 and 3.0 t ha^{-1} (T0, T1, T2, T3 and T4 respectively), which slowly sunk to the bottom after absorbing water. After 10 days, 40 rohu fingerlings of average weight 19±0.2 g were stocked in each tank. Subsequent fertilization was done at fortnightly intervals with cattle dung @ 1000 kg ha^{-1}.

Monitoring of water quality

Water quality parameters *viz.,* temperature, pH, dissolved oxygen, free carbon dioxide, total alkalinity, electrical conductivity (EC) and total hardness were analysed once every 15 days, starting on day 0 (fish stocking day). Water samples were collected between 0900 and 1000 hrs. EC and temperature were analysed using an ELICO conductivity meter, while pH was measured with an ELICO pH meter. Dissolved oxygen, free carbon dioxide, hardness and total alkalinity were analysed following standard methods (APHA, 1992).

Periphyton and plankton

Periphyton dry matter, ash, chlorophyll-*a*, pheophytin and plankton dry matter and ash were determined every 30 days. Periphyton was first scraped from a 2x2 cm area from three randomly selected bagasse from each tank for determining chlorophyll-*a* and pheophytin contents (Stirling, 1985). More periphyton was then carefully removed from known surface area of bagasse bundles in each tank for dry matter determination. Samples were dried at 100 °C to a constant weight to get the dry matter values and then the ash content was determined by incinerating the dry matter in a muffle furnace (4 h at 550 °C). Ash free dry matter (AFDM) was calculated by subtracting the ash value from the dry matter content.

Plankton samples were taken by filtering 100 l of water from each tank through a 60 µm mesh plankton net. The samples were dried and ignited to determine dry matter and ash contents, respectively.

Harvest and yield measurements

On termination of the experiment, fish were harvested by draining the tanks. All surviving fish were counted and weighed and the following parameters calculated

Specific growth rate, SGR (% per day) : $[(\text{Ln}W_{harv} - \text{Ln}W_{stock}) \div \text{no. of days}] \times 100$

Survival (%) : $[N_{harv} \div N_{stock}] \times 100$

Gross yield (kg ha^{-1}) : $[(W_{harv} \times N_{harv}) \div 25 \times 10{,}000] \div 1000$

where W_{stock} and W_{harv} are the mean individual fish weight and N_{stock} and N_{harv} the number of fish at stocking and harvest, respectively.

Statistical analyses

Comparison among treatments for various parameters was done by one-way analysis of variance (ANOVA), followed by Duncan's multiple range test at $p<0.05$ (Duncan, 1955; Snedecor and Cochran, 1968).

Results and discussion

Water quality

Water quality parameters were within the acceptable range for carps (Jhingran, 1991), with no drastic variation between treatments (Table 1). No effect of bamboo (Azim *et al*., 2001a; Keshavanath *et al*., 2004), hizol, jute stick (Azim, 2001) and bagasse substrate (Keshavanath *et al*., 2001) on water quality parameters was observed in other studies employing vertically planted/hung substrates. Periphyton mats are known to improve pond water quality by trapping suspended solids, organic matter breakdown, ammonium and nitrate uptake and nitrification enhancement (Azim and Little, 2006). The good water quality that prevailed in the experimental tanks during the study could

Table1. Range of water quality parameters observed in experimental tanks

Treatment	Temperature (°C)	pH	Dissolved oxygen (mg l^{-1})	Free carbon dioxide	Total alkalinity (mg l^{-1})	Electrical conductivity (dS m^{-1})	Hardness (mg l^{-1})
T0	24.0-25.6 (24.6±0.21)	8.4-9.4 (9.1±0.15)	7.2-8.8 (8.0±0.23)	0-4.4 (1.1±0.64)	222.6-316.4 (290.4±13.39)	0.45-0.51 (0.50±0.01)	154-218 (201±7.82)
T1	24.4-25.2 (24.8±0.13)	8.8-9.6 (9.4±0.11)	6.4-8.8 (7.8±0.31)	0-1.8 (0.4±0.24)	236.2-308.0 (284.2±9.28)	0.47-0.49 (0.49±0)	148-149 (149±0.18)
T2	24.2-25.8 (25.0±0.19)	8.8-9.6 (9.3±0.13)	6.0-9.6 (8.3±0.45)	0-2.4 (0.6±0.32)	217.3-324.8 (285.4±12.81)	0.44-0.50 (0.47±0.01)	138-148 (143±1.41)
T3	23.8-25.0 (24.4±0.16)	8.7-9.2 (9.1±0.06)	6.4-9.6 (8.0±0.50)	0-0.8 (0.2±0.10)	233.3-324.8 (280.3±0.01)	0.46-0.52 (0.50±0.01)	140-144 (143±0.57)
T4	24.0-25.4 (24.6±0.17)	8. 7-9.8 (9.2±0.14)	6.8-8.0 (7.2±0.15)	0-2.8 (0.7±0.38)	242.5-308.0 (287.9±9.31)	0.48-0.51 (0.48±0.01)	148-212 (167±8.63)

Values in brackets are averages ± S.E.

be related to cow dung application and periphyton development. During the experimental period, water temperature varied between 23.8 and 25.8 °C. Carps are reported to thrive well in a temperature range of 18.3 to 37.8 °C (Jhingran, 1991). pH was in the alkaline range (8.39-9.82), reflecting good productivity. Dissolved oxygen was high throughout the experimental duration, with a minimum level of 6 mg l^{-1}. Generally, cyprinids are capable of tolerating low oxygen levels of 3 mg l^{-1} (Huet, 1972). Total alkalinity was high and ranged from a minimum of 217.3 mg l^{-1} (T3) to a maximum of 324.8 mg l^{-1} (T3 and T4). Waters of higher alkalinity are considered more productive in terms of oxygen production and photosynthesis. Elnady *et al*. (2010) reported higher alkalinities in the organic fertilizer treatments (321.5-355.5 mg l^{-1}) in tilapia culture.

Periphyton and plankton

The AFDM (0.05 – 0.08 mg cm^{-2}) and total pigment contents (0.88 – 1.26 µg cm^{-2}) obtained are given in Table 2 and were somewhat lower as compared to values of 0.02 -1.98 mg for AFDM cm^{-2} and 0.76-1.96 µg for total pigment cm^{-2} (Keshavanath *et al.,* 2001) and values of 0.553 mg for AFDM cm^{-2} and 1.675 µg for chlorophyll-*a* m^{-2} (Gangadhar and Keshavanath, 2008) obtained with vertically suspended bagasse bundles as periphyton substrate (Table 2). This may be because of the difference in orientation of bagasse substrate in the water column. The difference in orientation of the substrates can affect the quantum of sunlight reaching the substrate, in turn, the population of photosynthetic periphytic community and hence the pigment content. The low total pigment content recorded in the present study reveals that periphytic community harbouring the bagasse substrate present in the tank bottom had comparatively less photosynthetic biota. According to Azim *et al*. (2002), only part of the periphyton organic matter is of algal nature, the rest being heterotrophic community.

T_1 and T_2 treatments recorded higher AFDM throughout the experiment (Fig. 1). However, there was a general decreasing trend in AFDM content over the experimental duration. All the treatments showed higher chlorophyll-*a* content on the 60^{th} day, which further decreased gradually. The decrease in periphyton dry matter and pigment content with time may be attributed to the greater grazing pressure as the fish biomass increased over the experimental period. Also, with increasing bagasse density there was a reduction in AFDM and pigment values per unit surface area. This could be because of nutrient limitation as there was increase in surface area with increasing substrate density, but the amount of nutrient input was the same in all the treatments. Keshavanath *et al*. (2001) reported similar findings in a carp polyculture trial.

The periphytic ash content showed increasing trend through the experiment. This is attributable to the fact that the bagasse substrate lying in the pond bottom is more prone to trap the settling inorganic matter mainly from soil origin getting into the water column through the activity of fish.

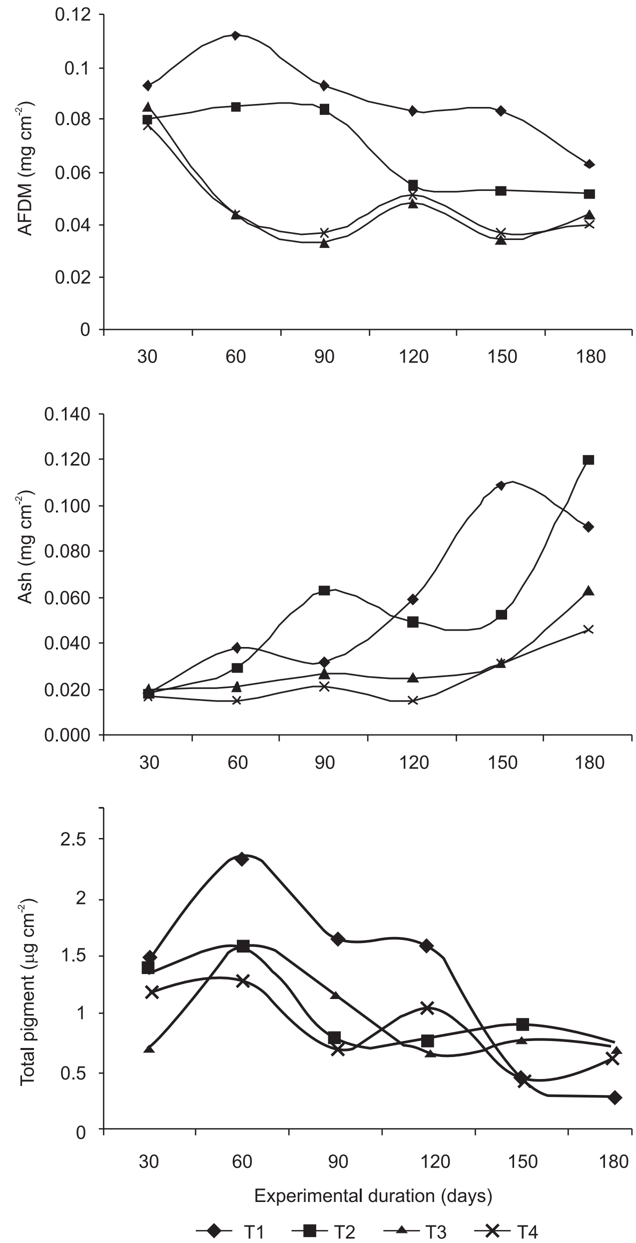

Fig. 1. Periphyton AFDM, ash and total pigment (chlorophyll-*a* + pheophytin) recorded in the four treatments

Mean plankton biomass was lower in the control (p>0.05); however, no clear differences could be seen in terms of plankton biomass between substrate densities (Table 2).

Mean weight of rohu increased from 1.89±0.18 g at stocking to 108±16 g at harvest in the control (T0) and to a maximum of 249±28 g in T3 treatment (Table 3). SGR followed a similar trend. AFDM of plankton from control

Table 2. AFDM, ash and total pigment (chlorophyll-*a* + pheophytin) content of periphyton and plankton

Treatment	Periphyton			Plankton	
	AFDM (mg cm^{-2})	Ash (mg cm^{-2})	Total pigment (µg cm^{-2})	AFDM (mg l^{-1})	Ash (mg l^{-1})
T0	—	—	—	0.26 ± 0.18	0.38 ± 0.23
T1	0.08 ± 0.02	0.06 ± 0.02	1.26 ± 0.34	0.36 ± 0.21	0.87 ± 0.27
T2	0.06 ± 0.02	0.06 ± 0.04	1.03 ± 0.26	0.41 ± 0.28	0.68 ± 0.25
T3	0.05 ± 0.02	0.03 ± 0.02	0.97 ± 0.32	0.34 ± 0.16	0.49 ± 0.18
T4	0.05 ± 0.02	0.02 ± 0.02	0.88 ± 0.12	0.44 ± 0.24	0.52± 0.16

Figures are means (± S.D.) of six monthly samplings (n = 6).

was lower compared to that of tanks with substrate, an indication of more efficient feeding on plankton in the former. Thus, the growth of control fish can be related to the abundance of planktonic organisms. Provision of bagasse resulted in significant increase in the growth of rohu at all the four densities tested. Though rohu is a column feeding fish mainly living on plankton (Jhingran and Pullin, 1985), it is known to efficiently graze on periphyton (Azim *et al.*, 2001a) and consume decaying suspended organic matter (Das and Moitra, 1955; Dewan *et al.*, 1991). The growth of rohu recorded under different bagasse treatments in this study confirms that it feeds directly on periphyton, even when the substrate is provided at the tank bottom. Periphyton substrates tend to entrap suspended organic material, which is likely to be more abundant when bagasse substrate is at the bottom. The entrapped organic material can not only provide nutrients to periphytic flora, but can also act as a food for fish. Increment in growth of rohu was progressive up to 2 t ha^{-1} bagasse density, beyond which it was not significant ($p>0.05$) with 2.5 t ha^{-1} and 3 t ha^{-1}. This could be related to the lower periphyton biomass available per unit surface area for the fish to graze.

In culture ponds, survival of rohu was higher compared to the control when bamboo poles were used as substrate (NFEP, 1997; Azim *et al.*, 2001a). However, it was not significantly different ($p>0.05$) among the treatments in the present study. Fish production increased by substrate addition. The gross yield in substrate tanks ranged from 2325.6 kg ha^{-1} 6 months^{-1} (T_0) to 3161.6 kg ha^{-1} 6 months^{-1} (T_2 treatment) (Table 3). Keshavanath *et al.* (2001) reported a production of 1310 kg ha^{-1} 6 months^{-1} in a polyculture study with catla, rohu and common carp, where sugarcane bagasse was suspended vertically in water column. The difference may be attributed to the fact that the stocking density used in the present study was higher (16000 ha^{-1} as compared to 10000 ha^{-1} used in polyculture). Further, species specific difference in periphyton utilisation is reported (Azim, 2001). It may be noted that, in the present study, only rohu, a species known to effectively utilise periphyton as compared to catla and common carp, was used. Out of the highest production of 3161.6 kg ha^{-1} in the present study, 1779.2 kg ha^{-1} could have been contributed by periphyton. Azim *et al.* (2001b) recorded a total production of 5800 kg ha^{-1} yr^{-1} for rohu, of which 2520 kg ha^{-1} yr^{-1} was estimated to have been contributed by periphyton grown on bamboo substrates. Ramesh *et al.* (1999) reported rohu and common carp production of 1235 kg ha^{-1} in 133 days, using sugarcane bagasse as substrate. In the present study, the increase in gross production due to bagasse substrate was 68, 129, 123 and 119% in 1.5, 2.0, 2.5 and 3.0 t bagasse ha^{-1} treatments, respectively. Azim (2001) recorded 77% higher gross production of rohu in monoculture and 180% higher production of rohu in polyculture with catla when bamboo was provided as substrate. *Labeo fimbriatus* showed 75% higher net production in bamboo-based periphyton culture

Table 3. Average body weight (±S.D.), survival and production of rohu obtained in the experimental tanks

Treatment	Average final weight (g)	Specific growth rate (%)	Survival (%)	Gross yield (kg ha^{-1})	Increase in production (%)
T0	108±16^{a}	2.24^{a}	80.0^{a}	1382.4^{a}	-
T1	171±21^{b}	2.50^{b}	85.0^{a}	2325.6^{b}	68.23
T2	247±24^{c}	2.70^{c}	80.0^{a}	3161.6^{c}	128.70
T3	249±28^{c}	2.71^{c}	77.5^{a}	3087.6^{c}	123.35
T4	229±21^{c}	2.66^{c}	82.5^{a}	3022.8^{c}	118.66

Initial av. wt. of fish was 1.9±0.2 g
Figures in the same column with same superscript do not differ significantly ($p>0.05$)

tanks (Keshavanath *et al*., 2002).

The results of this study demonstrate that sugarcane bagasse can also be applied in tank bottom as a substrate at 2.0 t ha^{-1} for increasing the production of rohu. Further research is needed to investigate the effect of water depth on the growth of periphyton and fish when bagasse substrate is applied in tank bottom.

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