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Effect of Various Loading Rates of Rice Straw on Physical, Chemical and Biological Parameters of Water

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ABSTRACT

An experiment was conducted to assess the effect of different loading rates of rice straw on the physical, chemical and biological parameters of fertilized water in 21 cemented tanks for 35 days using seven treatments with three replicates. Treatments were: Control (T1), rice straw mats with loading rate of 625 kg ha^{-1} (T2), 1,250 kg ha^{-1} (T3), 2,500 kg ha^{-1} (T4), 5,000 kg ha^{-1} (T5), 10,000 kg ha^{-1} (T6), 20,000 kg ha^{-1} (T7) on dry weight basis. Result showed that water quality deteriorated with increased loading rates of rice straw. Dissolved oxygen and pH were significantly lower in rice straw treatments than control. Transparency was significantly higher in the treatment T4 and lower in treatment T7. Total alkalinity, total ammonia, nitrite, TKN, total phosphorus, TSS, TVS and chlorophyll-a in treatment T7 was significantly higher than other treatments ($p<0.05$). Plankton, periphyton densities and bacterial load did not differ significantly among treatments. Dry matter and ash free dry matter of periphytons were significantly higher in the treatments T2, T3, T4 and T5. Chlorophyll-a concentration of periphytons was significantly higher in the treatment T3 than in the treatment T6 and T7. To sum up it can be said that the loading rate of 625 kg ha^{-1} appeared to be best among treatments. However, the experiment was carried out in tank without fish, so, effects of decomposition on fish growth and production needs to be assessed in ponds.

Key words: Rice straw, loading rate, water quality, periphyton

INTRODUCTION

Heterotrophic food production increased several fold by providing organic matter and suitable substrate (Schroeder, 1978). Attached algae and plankton are important part of energy fixation (Periyanayagi *et al*., 2007). Energy demand of herbivorous carps and tilapia can not be fulfilled only by plankton (Dempster *et al*., 1995; Hossain *et al*., 2007) they also need larger benthic algae, algal detritus or plant fodder, that can be harvested more efficiently (Yakupitiyage, 1993; Horne and Goldman, 1994). These types of algae can be grown in the substrates so that fish can harvest them efficiently (Dempster *et al*., 1993; Van Dam *et al*., 2002). Periphyton based aquaculture system generated a lot of interest in recent years (Tidwell *et al*., 2000). Microbial biofilm in the pond not only important as food of fishes (Banu and Khan, 2004), it also improves water quality in the pond (Thompson *et al.*, 2002). Various materials like tree branches (Welcomme, 1972; Hem and Avit, 1994), plastic (Shrestha and Knud-Hansen, 1994), split bamboo (Faruk-ul-Islam, 1996), rice straw (Mridula *et al.*, 2003, 2005), *Eichhornia* (Ramesh *et al.*, 1999; Ndimele, 2012), sugarcane bagasse (Dharmaraj *et al.*, 2002; Mridula *et al.*, 2005), kanchi (Wahab *et al.*, 1999; Azim *et al.*, 2002a), PVC pipes (Keshavanath *et al.*, 2001), bamboo (Azim *et al.*, 2002b, 2004; Keshavnath *et al.*, 2002; Azim *et al.*, 2004), jute stick (Azim *et al.*, 2002a) and stripe bamboo (Sahu *et al.*, 2007) have been used as substrate in periphyton based aquaculture system. Though bamboo is superior but it is very expensive to afford by small scale farmers. So, attention should be given on identification and using of low cost materials that enhance fish production (Van Dam *et al.*, 2002) and which is appropriate to rural aquaculture. Biodegradable materials like rice straw and sugarcane bagasse fall in this category (Ramesh *et al.*, 1999; Keshavanath *et al.*, 2001; Dharmaraj *et al.*, 2002; Mridula *et al.*, 2005). Besides being cost effective, these biodegradable substrates favour the growth of bacteria (Van Dam *et al.*, 2002) and also reduce clay turbidity in the pond (Yi *et al.*, 2003) which is advantage over non biodegradable material.

Rice straw is widely available in the farm in South Asia because it is widely cultivated in this region. It is a low cost material and has low nutritive value (Potikanond *et al.*, 1987). Farmers often burn them in the field instead of using wisely in the fish ponds that may pollute the environment. Rice straw can be used in fish ponds to mitigate turbidity (Yi *et al.*, 2003), to develop bacterial biofilm and periphyton (Ramesh *et al.*, 1999; Mridula *et al.*, 2003, 2005) that eventually enhance the fish production. However, excessive loading of rice straw can cause oxygen depletion and may kill fishes (Keshavanath *et al.*, 2001; Van Dam *et al.*, 2002). Hence, prior to applying to the pond, it is prerequisite to identify the appropriate loading level of rice straw that doesn't degrade water quality. No research has been done so far on it. Therefore, present experiment was conducted to investigate effects of different loading levels of rice straw on the physical, chemical and biological parameters of water.

MATERIALS AND METHODS

The experiment was carried out in 21 cement tanks of 5 m^2 (2.5×2×1.1 m) at Asian Institute of Technology, Thailand for thirty five days. The experiment was conducted in a completely randomized design and there were seven treatments, each with three replicates. The treatments were: without rice straw mats (T1, control), rice straw mats with loading rate of 625 kg ha^{-1} (T2), 1,250 kg ha^{-1} (T3), 2,500 kg ha^{-1} (T4), 5,000 kg ha^{-1} (T5), 10,000 kg ha^{-1} (T6) and 20,000 kg ha^{-1} (T7), on dry weight basis. Prior to start of the experiment all tanks were drained and dried for a week. Water was filled to 1 m deep. Then a mat was suspended in each tank by using bamboo pole. Tanks were fertilized weekly with urea and TSP at a rate of 28 kg^{-1} ha^{-1} $week^{-1}$ and 7 kg^{-1} ha^{-1} $week^{-1}$, respectively.

Temperature, Dissolved Oxygen (DO) and pH were monitored at three depths (10, 50 and 70 cm) from the water surface everyday at 06:00 h. Dial DO, temperature and pH were recorded at 06:00, 10:00, 14:00, 18:00 and 06:00 h every week. Secchi disk visibility was monitored daily at 0900-1000 h. Composite column water samples were collected weekly for the analysis of total alkalinity, Total Ammonia Nitrogen (TAN), nitrite nitrogen (nitrite-N), nitrate nitrogen (nitrate-N),Total Kjeldahl Nitrogen (TKN), Soluble Reactive Phosphorus (SRP), Total Phosphorus (TP) and Total Suspended Solids (TSS) and Total Volatile Solids (TVS) following standard methods (APHA, AWNA, WPCF, 1980). Chlorophyll-a of plankton were analyzed following Boyd and Tucker (1992). Plankton samples were taken every week. Five liter of sampled water was passed through plankton net to make a concentrated volume of 50 mL for the analysis. The samples were preserved in 6% formalin. Plankton density was estimated using the formula:

$$N = \frac{(P \times C \times 100)}{L}$$

Where:
N = The number of plankton units per liter 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

Periphyton samples were begun to collect after two weeks of rice straw mat suspension in the water column. Pieces of rice straw was cut from three different depths and wrapped in aluminum foil for weekly periphyton analysis. Each sample was transferred to an Erlenmeyer flask containing 50 mL distilled water and shaken in mechanical shaker for 3 h to detach periphytons from the straw. The straw was dried overnight in oven to get the dry weight. For taxonomic identification, samples were preserved in 6% formalin. Periphytons were counted using S-R cell under a binocular microscope. The number of periphyton units was estimated by the formula:

$$N = \frac{(P \times C \times 100)}{A}$$

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)
A = Area of rice straw (cm^2)

Dry matter of periphytons was estimated by filtering samples through pre-weighed and oven-dried filter papers and drying for 24 h in oven at 105°C. It was further combusted in muffle furnace at 550°C for 30 min to get ash content (%). Chlorophyll-a concentration was determined following the standard methods and bacteria number (CFU g^{-1}) was determined by total plate count method. Data were statistically analyzed by one way analysis of variance (ANOVA) and regression using SPSS (version 12.0). Tukey-test was performed to compare treatment means if significant differences were found by ANOVA. Differences were considered significant at an alpha level of 0.05 ($p<0.05$). All means were given with ±1 standard error (SE).

RESULTS

Dissolved oxygen (R^2 = 0.60), pH (R^2 = 0.70) and transparency (R^2 = 0.55) decreased with increased rice straw loading rates whereas total alkalinity (R^2 = 0.97), total ammonia nitrogen (R^2 = 0.06), nitrite nitrogen (R^2 = 0.60), total Kjeldahl nitrogen (R^2 = 0.28), total phosphorus (R^2 = 0.60), total suspended solids (R^2 = 0.63), total volatile solids (R^2 = 0.62) and Chlorophyll-a (R^2 =0.80) increased with rice straw loading rates ($p<0.05$, Table 1). The DO level decreased from two to three days of the start of the experiment (Fig. 1). Dissolved oxygen at three depths (10, 50 and 70 cm) and pH values were significantly lower in the rice straw treatments than in the control (Fig. 2, $p<0.05$). Transparency was significantly higher in the treatment T4 and lower in

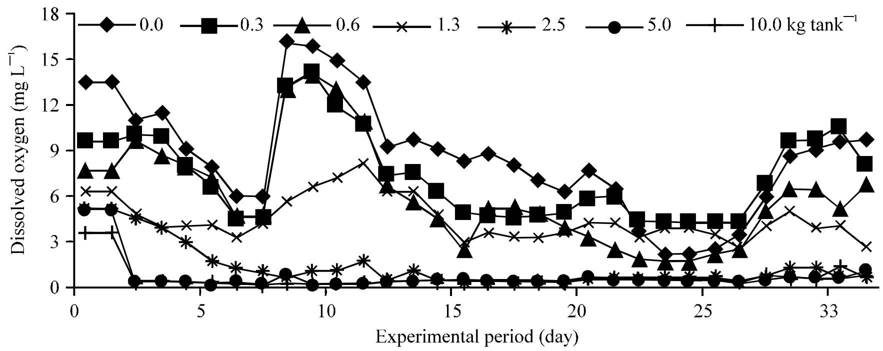

Fig. 1: Dissolved oxygen content in different treatments during the experimental period

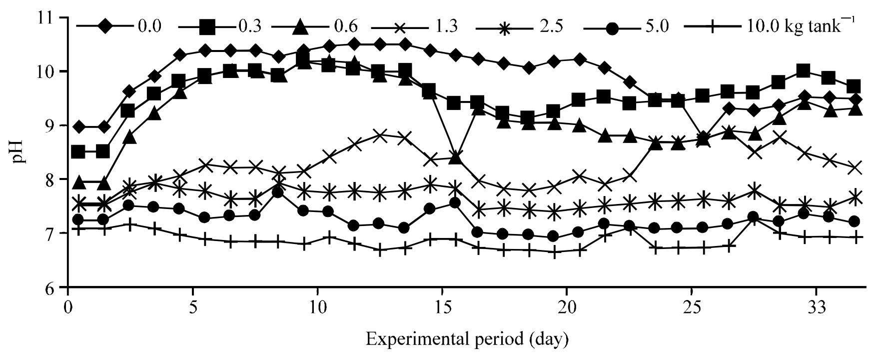

Fig. 2: pH value in different treatments during the experimental period

Table 1: Summary of water quality parameters in different treatments during experimental period

	Treatment						
Parameter	T1	T2	T3	T4	T5	T6	T7
Temperature (°C) (06:00 h)	28.40±0.2	28.3±0.1	28.30±0.1	28.30±0.20	28.1±0.1	28.1±0.2	27.8±0.1
DO (mg L^{-1}) (06:00 h) at							
10 cm	9.40±0.5^{a}	8.0±0.50^{ab}	6.50±1.2^{bc}	4.70±0.40^{c}	1.5±0.3^{d}	0.8±0.2^{d}	0.8±0.2^{d}
50 cm	8.30±0.5^{a}	7.2±0.50^{a}	5.90±1.1^{ab}	4.50±0.30^{b}	1.4±0.3^{c}	0.7±0.2^{c}	0.7±0.2^{c}
70 cm	8.10±0.4^{a}	6.9±0.50^{ab}	5.70±1.0^{bc}	4.30±0.30^{c}	1.2±0.2^{d}	0.6±0.2^{d}	0.6±0.1^{d}
pH (0600 h)	9.90±0.1^{a}	9.6±0.20^{ab}	9.20±0.3^{b}	8.20±0.20^{c}	7.6±0.1^{d}	7.2±0.1^{de}	6.9±0.0^{e}
Transparency (cm)	60.00±8.0^{abc}	63.00±6.00^{abc}	58.00±8.0^{bcd}	76.00±4.00^{a}	53±5^{bcd}	41±3de	31±2^{e}
Alkalinity (mg L^{-1})	81.00±3.0^{f}	92.00±2.00^{e}	99.00±4.0^{de}	102.00±4.00^{d}	123±4^{c}	145±2^{b}	190±1^{a}
TAN (mg L^{-1})	0.23±0.01	0.16±0.04	0.16±0.04	0.09±0.02	0.17±0.04	0.13±0.04	0.23±0.02
NO_2-N (mg L^{-1})	0.004±0.001^{b}	0.005±0.002^{b}	0.003±0.001^{b}	0.002±0.000^{b}	0.005±0.002^{b}	0.006±0.000^{b}	0.013±0.001^{a}
NO_3-N (mg L^{-1})	0.10±0.00	0.13±0.01	0.10±0.02	0.10±0.01	0.11±0.01	0.09±0.02	0.12±0.02
TKN (mg L^{-1})	1.89±0.15^{bc}	2.00±0.16^{bc}	2.35±0.17^{ab}	1.83±0.13^{bc}	1.73±0.04^{c}	2.27±0.36^{abc}	2.61±0.14^{a}
PO_4-P (mg L^{-1})	0.36±0.06	0.41±0.14	0.38±0.13	0.55±0.08	0.62±0.04	0.61±0.05	0.76±0.07
TP (mg L^{-1})	0.83±0.12^{bc}	0.81±0.22^{c}	0.79±0.21^{c}	0.97±0.11^{bc}	1.13±0.03^{bc}	1.25±0.11^{ab}	1.58±0.13^{a}
TSS (mg L^{-1})	19.00±4.00^{bc}	14.00±2.00^{c}	18.00±4.0^{bc}	10.00±2.00^{c}	15±4^{bc}	26±5^{b}	42±4^{a}
TVS (mg L^{-1})	17.00±4.00^{bc}	12.00±1.00^{c}	16.00±4.0^{bc}	9.00±2.00^{c}	13±3^{bc}	22±4^{b}	36±4^{a}
Chlorophyll-a (µg L^{-1})	28.00±8.00^{c}	44.00±9.00^{c}	49.00±17.0^{c}	71.00±22.00^{c}	54±4^{c}	134±16^{b}	197±29^{a}

Different superscript letters in the same row are significantly different at $p<0.05$

the treatment T7 ($p<0.05$). Total alkalinity, nitrite nitrogen, total Kjeldahl nitrogen, total phosphorus, total suspended solids, total volatile solids and chlorophyll-a content were significantly higher in the treatment T7 than in the control and the treatments T2, T3, T4, T5 and T6 ($p<0.05$). Temperature, soluble reactive phosphorus, nitrate nitrogen and total ammonia nitrogen did not show significant differences among treatments ($p>0.05$).

The mean phytoplankton number ranged from 1,640,009 L^{-1} (T1) to 4,250,283 L^{-1} (T3) and zooplankton ranged from 6,044 L^{-1} (T7) to 20,867 L^{-1} (T3). Total number of plankton varied from 1,653,200±303,105 (T1) to 4,271,150±2,987,660 (T3). There were no significant differences in phytoplankton, zooplankton and plankton densities among all treatments ($p>0.05$). Phytoplankton community was comprised of 7 major groups. In total 51, 55, 50, 58, 60, 59 and 50 phytoplankton genera were identified in treatments T1, T2, T3, T4, T5, T6 and T7, respectively. Among the groups of phytoplankton, Cyanophyceae showed significant difference between the treatments ($p<0.05$, Table 2). The highest average number of Cyanophyceae was found in treatment T2. Among different groups of phytoplankton Chlorophyceae was the dominant in all the treatments. Zooplankton was comprised of 8 groups. There were 25, 22, 21, 22, 22, 18 and 21 zooplankton genera in treatments T1, T2, T3, T4, T5, T6 and T7, respectively. Among different groups, Ciliata showed significant difference between treatments ($p>0.05$, Table 3). Highest number of ciliates was counted in treatment T6.

Periphyton community was composed of 10 phytoplankton and 6 zooplankton groups. Periphyton genera found in treatments T2, T3, T4, T5, T6 and T7 were 39, 41, 41, 43, 32 and 37, respectively. However, periphyton density also did not differ significantly among treatments ($p>0.05$, Table 4). Dry matter and ash free dry matter of periphytons were significantly higher in the treatments T2, T3, T4 and T5 than in the treatments T6 and T7 ($p<0.05$, Table 5). Ash content was significantly higher in the treatment T2 than in T4 and T7 ($p<0.05$). Bacteria total plate count did not differ significantly among treatments ($p>0.05$, Table 4).

DISCUSSION

The study showed that treatments had significant effect on water quality. Water quality found to deteriorate at high rice straw loading rates. Dissolved oxygen and pH was critically low at higher rice straw loading rates. Olaleye and Adedeji (2005) also reported that pH in the open water found to be lower in the water with palm oil effluents. Lower dissolved oxygen concentration at higher straw loading rate was probably due to intense decomposition of rice straw that consumed dissolved oxygen from water. This can be attributed to the increased biological oxygen demand in water with predominant heterotrophic food production which accounts for bulk of the oxygen consumption (Moriarty, 1997; Hassan and Javed, 1999). Physicochemical properties of pond are important for food production (Ndome *et al*., 2011). Mridula *et al*. (2003) reported similar type of results with rice straw and Masifwa *et al*. (2004) found same results with water hyacinth decomposition in water. However, DO content was safe in low rice straw loading levels. Since decomposition released CO_2, pH was brought down in the water (Kusakabe *et al*., 2000). Organic and inorganic fertilizer increase the fish food organisms for fish (Ghaffar *et al*., 2002), though same rate of fertilization was applied, nitrite-nitrogen, total Kjeldahl nitrogen and total phosphorus were higher in the high loading treatments. This can be attributed to nutrients leaching from rice straw to water. The nutrients released from rice straw and fertilizer subsequently increased phytoplankton and hence total suspended and volatile solids (Olaleye and Adedeji, 2005). Transparency is a measure of turbidity and has a reciprocal relationship with Chlorophyll-a and TSS. Present experiment also

Table 2: Abundance of phytoplanktons (units L^{-1}) in tank water in different treatments

	Treatment						
Genus	T1	T2	T3	T4	T5	T6	T7
Bacillariophyceae							
Cocconeis	0±0	0±0	0±0	0±0	0±0	46±46	0±0
Coscinodiscus	0±0	0±0	58,336±58,336	1,375±794	22,951±6,939	0±0	2,292±2,292
Cyclotella	5,478±3,564	2,500±2,500	43,958±40,569	5,133±2,512	11,264±581	46±46	21,354±13,639
Navicula	8,364±8,318	1,07,225±43,104	84,584±39,040	44,092±38,006	1,58,925±1,44,501	98,471±66,377	67,953±53,763
Surirella	0±0	31,390±8,283	9,167±9,167	23,467±23,467	52,081±52,081	3,333±3,333	8,333±8,333
Subtotal	13,841±11,844	1,41,115±46,318	1,37,709±75,260	72,692±63,854	2,22,270±1,96,151	1,01,850±65708	97,639±57,939
Chlorophyceae							
Ankistrodesmus	4,167±4,167	16,667±16,667	8,23,750±8,05,073	0±0	1,833±1,833	50,000±28,868	29,164±29,164
Asterococcus	0±0	0±0	0±0	183±183	0±0	46±46	0±0
Botryococcus	0±0	0±0	0±0	0±0	0±0	0±0	458±458
Cateria	25,000±25,000	11,112±11,112	20,625±20,625	5,683±5,683	0±0	83,658±39,458	37,496±3,74,596
Chaetophora	0±0	0±0	0±0	0±0	0±0	0±0	458±458
Chlamydomonas	120,833±120,833	0±0	107,708±107,708	6,417±6,417	0±0	289,717±202,382	70,826±70,826
Chlorella	8,737±8,139	78,890±30,977	13,750±13,750	12,283±12,283	27,777±27,777	49,067±23,478	37,496±3,74,596
Chlorococcum	0±0	2,29,167±1,60,132	4,583±4,583	4,583±4,583	0±0	0±0	0±0
Chodatella	101±101	4,167±4,167	9,167±9,167	0±0	0±0	0±0	4,166±4,166
Closterium	1,109±1,109	0±0	0±0	0±0	20,833±20,833	8,333±8,333	458±458
Coelastrum	221,085±220,707	91,391±42,221	224,792±1,94,381	40,700±13,357	56,928±54,879	69,388±53,372	37,725±37,382
Coleochaete	0±0	0±0	0±0	1,650±1,650	6,944±6,944	0±0	4,166±4,166
Cosmarium	2,017±2,017	9,167±9,167	36,458±21,676	1,833±1,213	8,319±6,269	4,167±4,167	5,541±5,541
Crucigenia	0±0	1,667±1,667	0±0	0±0	0±0	0±0	0±0
Dictyosphaerium	771,993±770,254	522,227±396,433	2119,792±2119,792	55,000±55,000	28,693±27,330	91,146±44,701	124,988±124,988
Eudorina	333,434±333,283	35,834±14,167	158,958±117,147	65,633±65,633	6,6484±39,674	53,425±48,369	33,976±27,080
Gloeocystis	303±303	0±0	0±0	2,383±2,383	3,208±3,208	46±46	0±0
Golenkinia	30±30	8,333±8,333	2,292±2,292	2,017±2,017	9,236±6,129	0±0	458±458
Gonatozygon	0±0	0±0	8,333±8,333	0±0	0±0	0±0	917±917
Micractinium	0±0	0±0	0±0	0±0	3,208±3,208	10,971±5,706	0±0
Micrasterias	0±0	0±0	0±0	8,250±4,763	1,375±1,375	0±0	0±0
Mougeotia	0±0	7,778±2,900	4,583±4,583	550±550	10,416±10,416	7,546±3,774	4,166±4,166
Onychonema	0±0	5,556±5,556	0±0	367±367	0±0	0±0	0±0
Oocystis	4,520±3,992	70,836±43,504	50,417±50,417	20,167±20,167	0±0	0±0	4,166±4,166
Pandorina	82,317±38,264	1605,912±1547,345	1503,631±949,024	829,308±414,067	472,680±120,496	415,063±187,844	63,832±15,376
Pediastrum	4,167±4,167	0±0	4,167±4,167	8,708±4,785	1,146±606	0±0	0±0
Planktosphaeria	16,727±16,636	33,333±33,333	21,111±13,750	917±458	458±458	92±92	12,499±12,499
Pyrobotrys	202±202	833±833	4,167±4,167	1,650±840	183,722±178,794	305,471±223,153	705,013±703,638
Radiococcus	0±0	0±0	13,750±13,750	0±0	0±0	0±0	0±0
Scenedesmus	26,109±24,464	679,168±401,320	627,500±343,278	18,517±5,594	537,473±502,176	229,396±181,333	1,604±999
Selenastrum	0±0	16,668±16,668	4,583±4,583	367±367	10,416±10,416	0±0	0±0
Spirogyra	605±605	1,667±1,667	8,333±8,333	458±458	5,305±3,008	0±0	229±229
Tetraedron	0±0	833±833	5,556±5,556	1,283±799	24,763±24,079	0±0	229±229
Tetraspora	0±0	15,000±11,456	2,292±2,292	0±0	6,944±6,944	0±0	0±0
Ulothrix	252±252	12,778±2,650	6,875±6,875	1,100±1,100	10,416±10,416	0±0	4,166±4,166
Volvox	0±0	0±0	0±0	0±0	229±229	0±0	0±0
Subtotal	1623,707±1563,230	3458,983±1427,937	5787,173±3025,776	1090,008±315,975	1498,808±993,705	1667,529±711,142	184,200±1089,100

Table 2: Continue

	Treatment						
Genus	T1	T2	T3	T4	T5	T6	T7
Chrysophyceae							
Chrysococcus	0±0	0±0	0±0	0±0	0±0	0±0	24,998±24,998
Uroglenenopsis	0±0	0±0	0±0	3,667±3,667	0±0	138±138	0±0
Ochromonas	0±0	0±0	0±0	2,200±2,200	0±0	0±0	0±0
Mallomonas	0±0	28,333±23,511	0±0	1,192±642	0±0	0±0	0±0
Prymnesium	0±0	0±0	0±0	3,667±3,667	0±0	0±0	0±0
Subtotal	0±0	28,333±23,511	0±0	10,725±10,045	0±0	138±138	24,998±24,998
Cryptophyceae							
Chroomonas	0±0	0±0	0±0	0±0	0±0	504±504	0±0
Gonyostomum	12,500±12,500	12,500±12,500	0±0	12,467±12,467	0±0	8,333±8,333	16,665±16,665
Cryptomonas	0±0	0±0	0±0	0±0	3,472±3,472	0±0	0±0
Subtotal	12,500±12,500	12,500±12,500	0±0	12,467±12,467	3,472±3,472	8,333±8,333	16,665±16,665
Cyanophyceae							
Anabaena	5,104±3,786	2,778±2,778	4,583±4,583	1,833±1,833	3,472±3,472	550±550	24,998±24,998
Anacystis	0±0	10,000±5,204	4,583±4,583	1,650±1,650	0±0	8,333±8,333	0±0
Aphanocapsa sp,	0±0	145,282±73,185	2,292±2,292	48,125±47,439	118,051±118,501	62,500±62,500	6,417±6,417
Chroococcus	0±0	3,611±2,469	0±0	1,558±1,293	458±458	963±963	0±0
Gloeocapsa	0±0	0±0	0±0	183±183	0±0	92±92	0±0
Gomphosphaeria	0±0	833±833	2,292±2,292	2,383±2,383	86,802±86,802	0±0	0±0
Merismopedia	131±131	4,167±4,167	0±0	0±0	0±0	0±0	0±0
Microcystis	22,376±20,103	265,562±133,980	6,875±6,875	9,717±5,648	917±458	92±92	5,083±3,792
Nostoc	0±0	0±0	0±0	0±0	458±458	0±0	0±0
Oscillatoria	38,508±37,006	131,113±41,988	85,486±58,398	29,150±29,150	81,748±53,353	81,579±43,762	83,495±46,534
Spirulina	0±0	5,833±3,632	4,583±4,583	2,200±2,200	3,472±3,472	0±0	5,541±3,677
Subtotal	66,120±60,692	569,178±1,30,839	110,695±55,713	96,800±87,189	2,95,378±2,63,850	154,108±111,488	125,533±71,179
Euglenophyceae							
Euglena	5,931±3,622	82,780±13,493	373,059±267,699	18,333±8,744	325,995±269,936	511,800±363,506	226,609±131,234
Euglenopsis	0±0	0±0	0±0	0±0	0±0	46±46	0±0
Lepocinclis	0±0	0±0	0±0	0±0	0±0	1,696±1,696	0±0
Phacus	352±220	13,056±1,945	127,293±99,635	2,567±1,192	65,477±61,011	19,196±10,620	31,643±22,000
Trachalomonas	0±0	0±0	0±0	0±0	0±0	138±138	0±0
Subtotal	6,284±3,523	95,835±15,025	500,351±367,233	20,900±9,932	391,472±330,857	532,875±372,843	258,253±153,002
Xanthophyceae							
Botrydium	504±504	0±0	0±0	0±0	0±0	0±0	0±0
Centritractus	0±0	0±0	0±0	458±458	0±0	0±0	0±0
Subtotal	504±504	0±0	0±0	458±458	0±0	0±0	0±0
Unknown	0±0	5,556±5,556	0±0	275±275	6944±6944	0±0	917±917
Total No, of phytoplankton	1640,009±173,874	279,3407±567,193	4250,283±1731,094	2586,524±321,033	2065,010±610,557	2038,742±816,198	1926,525±684,137

Different superscript letters in the same row are significantly different at ($p<0.05$)

Table 3: Abundance of zooplanktons (units L^{-1}) in tank water in different treatments

	Treatment						
Genus	T1	T2	T3	T4	T5	T6	T7
Crustacea							
Alona	589±320	444±444	0±0	133±133	0±0	0±0	0±0
Cyclops	0±0	444±222	700±436	513±408	67±67	200±200	183±183
Daphnia	244±244	222±222	0±0	0±0	326±326	0±0	0±0
Diaphanosoma	244±244	0±0	0±0	0±0	0±0	0±0	550±550
Moina	0±0	444±444	0±0	0±0	896±896	67±67	183±183
Monostyla	0±0	0±0	0±0	0±0	0±0	0±0	67±67
Nauplius	1,222±647	2,289±963	1,300±700	1,893±1,473	967±524	747±542	833±833
Ostracod	0±0	0±0	0±0	178±178	0±0	0±0	0±0
Cypris	0±0	0±0	0±0	0±0	221±13	147±147	0±0
Cypridopsis	0±0	222±222	0±0	0±0	0±0	0±0	0±0
Candona	0±0	0±0	0±0	0±0	67±67	0±0	0±0
Subtotal	2,300±824	4,067±1,968	2,000±1,000	2,718±1,732	2544±751	1160±764	1817±1117
Rotifera							
Ascomorpha	0±0	0±0	0±0	0±0	0±0	0±0	0±0
Asplanchan	3,233±1,703	15,490±9,683	3,133±467	953±652	4,047±3,189	2,160±802	1,750±236
Brachionus	11,378±4,022	19,734±4,775	10,767±1,822	14,522±7,369	6,764±2,202	11,280±3,370	1,867±830
Conochilus	0±0	0±0	0±0	0±0	0±0	0±0	0±0
Filinia	489±489	0±0	0±0	0±0	0±0	0±0	0±0
Keratella	489±489	2,822±1,172	533±33	264±201	1,391±625	280±140	317±164
Lecane	0±0	0±0	0±0	0±0	73±73	0±0	0±0
Polyarthra	0±0	0±0	0±0	0±0	0±0	0±0	0±0
Trichocerca	2,322±1,644	222±222	0±0	411±153	0±0	73±73	200±200
Subtotal	17,911±6,416	38,269±15,150	14,433±1,386	16,151±8,246	12,275±12,275	13,793±4,004	4,133±892
Ciliata							
Tintinnopsis	1,178±640	1,400±702	167±167	1,389±841	326±326	340±239	383±192
Paramecium	589±320	0±0	1,900±1,069	2,127±1,911	3,364±1,520	11,027±2,145	4,817±3,951
Subtotal	1,767±960	1,400±702	2,067±1,233	3,515±1,666	3,690±1,371	11,367±2,287	5,200±3,763
Sarcodina							
Arcella	0±0	0±0	0±0	267±267	73±73	0±0	0±0
Amoeba	0±0	0±0	0±0	0±0	0±0	0±0	67±67
Centropyxis	0±0	0±0	0±0	236±128	148±75	73±73	0±0
Parundella	0±0	0±0	0±0	0±0	0±0	0±0	0±0
Difflugia	222±222	0±0	0±0	0±0	0±0	0±0	0±0
Euglypha	0±0	0±0	0±0	89±89	0±0	0±0	0±0
Holophrya	222±222	0±0	0±0	0±0	0±0	0±0	0±0
Subtotal	444±444	0±0	0±0	591±392	221±13	73±73	67±67
Monogononta							
Anuraeopsis	0±0	0±0	0±0	0±0	147±147	140±70	133±133
Colurella	0±0	0±0	0±0	0±0	148±75	0±0	0±0
Lepadella	0±0	0±0	0±0	0±0	0±0	0±0	0±0
Mytilina	0±0	222±222	0±0	0±0	0±0	0±0	0±0
Pleocoma	222±222	0±0	0±0	0±0	0±0	0±0	0±0
Subtotal	222±222	222±222	0±0	0±0	295±74	140±70	133±133
Gastropoda							
Creseis	367±367	0±0	0±0	0±0	0±0	0±0	0±0
Subtotal	367±367	0±0	0±0	0±0	0±0	0±0	0±0

Table 3: Continue

	Treatment						
Genus	T1	T2	T3	T4	T5	T6	T7
Hydrozoa							
Gastroblasta	0±0	0±0	0±0	44±44	311±219	0±0	333±333
Stauropora	0±0	244±244	0±0	0±0	0±0	0±0	0±0
Phialidium	0±0	244±244	0±0	0±0	0±0	0±0	0±0
Lensia	222±222	0±0	0±0	0±0	0±0	0±0	1,200±1,200
Subtotal	222±222	489±489	0±0	44±44	311±219	0±0	1,533±1,533
Siphonophora	2,933±2,240	1,600±581	0±0	1,544±335	1,418±848	2,647±375	183±183
Unknown	856±441	444±222	0±0	73±73	1,132±1,024	880±880	0±0
Total No. of zooplankton	1.31.912±1.963	18.942±1.337	20.867±7.464	11.738±1.700	13.949±2.478	14.875±1.568	6.044±950

Different superscript letters in the same row are significantly different at p<0.05

Table 4: Abundance of periphyton (units cm^{-2}) and bacteria ($\times 10^6$ CFU g^{-1}) on rice straw in different treatments

	Treatment					
Genus	T2	T3	T4	T5	T6	T7
PHYTOPLANKTON						
Bacillariophyceae						
Chodatella	10,020±10,020	0±0	0±0	0±0	0±0	0±0
Coscinodiscus	0±0	2,101±2,101	0±0	5,164±5,164	0±0	8,842±5,042
Cyclotella	1,165±1,165	293±293	1,072±1,072	17,001±7,131	0±0	5,601±626
Cymbella	0±0	0±0	259±259	12,429±12,429	7,666±7,666	0±0
Fragilaria	0±0	0±0	5,429±5,429	12,911±12,911	0±0	0±0
Gyrosigma	0±0	0±0	0±0	0±0	0±0	2,015±2,015
Gomphonema	0±0	0±0	0±0	0±0	0±0	1,48,413±1,48,413
Melosira	0±0	0±0	0±0	5,865±3,290	0±0	0±0
Navicula	2,23,651±1,91,780	1,11,856±87,202	2,40,313±8,842	5,26,627±1,98,048	10,66,117±4,46,052	4,57,659±2,67,057
Nitzschia	0±0	0±0	0±0	2,072±	0±0	0±0
Rhabdonema	0±0	1,786±1,786	0±0	0±0	0±0	0±0
Surirella	1,74,845 ±1,66,855	12,396±6,410	1,00,747±73,384	5,42,498±1,28,790	66,242±24,383	85,806±41,461
Skeletonema	0±0	0±0	0±0	0±0	7,170±4,453	0±0
Bacteriastrum	0±0	0±0	0±0	0±0	0±0	1,066±1,066
Subtotal	4,09,682±3,53,253	1,28,432±93,379	3,47,819±69,913	11,24,566±2,83,165	11,47,195±4,80,874	7,09,402±2,08,667
Chlorophyceae						
Actinastrum	0±0	24±24	0±0	0±0	10,300±10,300	0±0
Ankistrodesmus	2,505±2,505	33,414±30,605	0±0	72,442±25,900	5,398±5,398	52,289±21,069
Basicladia	0±0	0±0	0±0	1,264±1,264	0±0	0±0
Botryococcus	0±0	0±0	0±0	15,736±8,022	0±0	1,066±1,066
Carteria	33,732±32,000	0±0	0±0	0±0	0±0	0±0
Chaetophora	1,418±742	24±24	1,072±1,072	0±0	0±0	0±0
Characium	0±0	0±0	0±0	10,115±10,115	0±0	0±0
Chlamydomonas	0±0	0±0	54,678±54,678	0±0	2,07,0,48 ±1,91,806	0±0
Chlorella	567±567	1,051±1,051	0±0	4,143±4,143	5,254±2,630	69,295±44,930
Chlorococcum	5,669±5,669	0±0	34,012±25,370	0±0	41,889±17,384	47,646±25,026
Cladophora	0±0	12±12	0±0	0±0	0±0	0±0
Closterium	0±0	0±0	0±0	0±0	0±0	9,593±9,593
Coelastrum	2,268±2,268	14,393±1,181	96,311±60,540	21,601±21,601	10,221±10,221	0±0
Coleochaete	0±0	0±0	2,144±2,144	0±0	28,107±28,107	24,122±13,023
Cosmarium	0±0	14,497±7,251	2,920±1,881	35,455±14,574	3,905±2,214	11,422±11,422
Dictyosphaerium	4,175±4,175	0±0	26,558±9,802	0±0	23,140±19,234	0±0

Table 4: Continue

	Treatment					
Genus	T2	T3	T4	T5	T6	T7
Draparnaldia	0±0	4,938±2,738	0±0	2,072±2,072	0±0	0±0
Eudorina	6,742±3,371	8,825±4,646	22,180±19,529	11,082±6,119	15,331±15,331	0±0
Gloeocapsa	835±835	0±0	1,534±1,534	0±0	1,350±1,350	0±0
Gloeocystis	0±0	0±0	0±0	3,336±3,336	2,555±2,555	3,198±3,198
Golenkinia	0±0	37±37	0±0	0±0	0±0	5431±3942
Gonatozygon	0±0	2,101±2,101	0±0	0±0	1,350±1,350	1,007±1,007
Kirchneriella	0±0	2,101±2,101	1,534±1,534	0±0	0±0	0±0
Lobomonas	0±0	0±0	0±0	1,264±1,264	0±0	0±0
Microspora	0±0	1,051±1,051	0±0	0±0	0±0	0±0
Mougeotia	0±0	1,786±1,786	3,373±1,994	0±0	0±0	0±0
Oedogonium	1,701±1,701	0±0	1,839±957	24,023±24,023	6,675±3,602	4,365±4,365
Onychonema	0±0	2,101±2,101	0±0	0±0	0±0	0±0
Oocystis	1,402±738	0±0	2,577±1,573	0±0	2,555±2,555	0±0
Pandorina	31,180±31,180	14,509±7,239	57,190±27,765	18,051±6,900	15,331±15,331	0±0
Pediastrum	0±0	0±0	0±0	4,654±2,369	0±0	0±0
Planktosphaeria	835±835	0±0	5,675±4,171	0±0	0±0	44,855±4,936
Pyrobotrys	0±0	0±0	0±0	2,072±2,072	0±0	0±0
Scenedesmus	4,20,805±1,98,244	201,092±100,200	1,00,394±44,650	5,34,899±1,27,904	10,86,737±9,31,251	70784±14835
Selenastrum	0±0	8,193±6,680	0±0	0±0	0±0	2,073±1,038
Spirogyra	0±0	0±0	0±0	0±0	0±0	1,007±1,007
Tetraodon	5,010±5,010	10,319±6,180	767±767	40,080±19,395	1,350±1,350	7,504±2,960
Ulothrix	0±0	3,887±1,963	0±0	9,307±4,737	4,049±4,049	23,115±13,176
Xanthidium	0±0	1,051±1,051	0±0	0±0	0±0	0±0
Zygnema	835±835	0±0	1,072±1,072	0±0	0±0	0±0
Subtotal	519,677±1,79,258	325,407±166,172	415,832±194,363	811,596±124,303	1472,543±1224,670	3,78,771±66,920
Cyanophyceae						
Anabaena	2,331±2,331	6,408±4,917	259±259	2,072±2,072	0±0	0±0
Aphanocapsa	35,072±35,072	0±0	74,629±12,511	0±0	91,986±91,986	17,460±17,460
Calothrix	0±0	3,596±3,559	0±0	1,264±1,264	0±0	0±0
Chroococcus	3,480±2,675	8,405±8,405	12,082±6,044	4,143±4,143	0±0	3,198±3,198
Coelosphaerium	835±835	0±0	0±0	0±0	0±0	0±0
Gloeocapsa	567±56	1,786±1,786	1,072±1,072	0±0	0±0	0±0
Merismopedia	0±0	6,432±4,901	0±0	2,529±2,529	0±0	0±0
Microcystis	64,333±28,924	0±0	0±0	22,165±12,237	2,699±2,699	35,778±17,160
Oscillatoria	166,920±43,034	893,601±581,197	43,294±14,127	535,054±248,199	431,614±2,82,529	760,920±3,35,472
Rivularia	0±0	24±24	0±0	0±0	0±0	0±0
Spirulina	0±0	1,051±1,051	1,543±771	8,797±5,408	21,791±19,801	9,407±6,478
Schizothrix	0±0	12±12	0±0	0±0	0±0	0±0
Subtotal	273,538±62,494	921,315±594,232	132,879±19,372	576,023±2,55,559	548,090±3,92,867	826,763±3,75,132
Euglenophyceae						
Euglena	1,165 ±1,165	87,835±45,148	38,762±35,304	1,54,273±71,930	8,58,654±5,01,894	1,92,149±92,267
Phacus	0±0	0±0	1,072±1,072	0±0	8,520±3,461	6,049±1,657
Trachelomonas	15,673±7,856	4,938±2,738	8,298±2,802	5,164±5,164	2,2501±19,493	0±0
Subtotal	16,838±8,564	92,772±47,304	48,132±35,590	1,59,438±75,127	8,89,675±5,02,185	1,98,199±90,732
Raphidophyceae						
Gonyostomum	2,913±2,913	0±0	0±0	0±0	0±0	
Xanthophyceae						
Vaucheria	0±0	0±0	0±0	1,264±1,264	0±0	1,455±1,455
Dinophyceae						
Gymnodinium	0±0	0±0	0±0	0±0	0±0	1,455±1,455

Table 4: Continue

	Treatment					
Genus	T2	T3	T4	T5	T6	T7
Oligohymenophorea						
Colpidium	0±0	0±0	0±0	0±0	2,060±2,060	1,066±1,066
Chrysophyceae						
Uroglena	0±0	0±0	259±259	0±0	0±0	2,910±2,910
Mallomonas	0±0	0±0	0±0	2,529±2,529	0±0	0±0
Subtotal	0±0	0±0	259±259	2,529±2,529	0±0	2,910±2,910
Siphonophora	12,665±5,144	0±0	11,866±5,542	0±0	6,675±3,602	0±0
Unknown	3,166±2,045	0±0	9,535±4,568	0±0	2,555±2,555	0±0
ZOOPLANKTON						
Crustacea						
Nauplius	567±567	2,836±1,555	259±259	12,400±9,464	0±0	4,365±4,365
Cypris	3,480±2,675	0±0	517±517	0±0	0±0	0±0
Subtotal	4,047±2,544	2,836±1,555	776±776	12,400±9,464	0±0	4,365±4,365
Rotifera						
Asplanchan	1,717±982	1,051±1,051	776±776	4,654±2369	6,748±6748	27,725±15,712
Brachionus	1,402±738	6,304±6,304	0±0	2,582±2,582	0±0	0±0
Conochilus	0±0	0±0	0±0	0±0	2555±2555	0±0
Lecane	583±583	0±0	776±776	2,072±2,072	0±0	0±0
Trichocerca	0±0	0±0	259±259	0±0	0±0	0±0
Subtotal	3,701±757	7,354±7,354	1,793±1,423	9,307±4,737	9,303±5,901	27,725±15,712
Ciliata						
Tintinnopsis	583±583	49±49	0±0	7,746±7,746	0±0	0±0
Paramecium	835±835	0±0	5,683±2,923	0±0	0±0	0±0
Subtotal	1,418±742	49±49	5,683±2,923	7,746±7,746	0±0	0±0
Sarcodina						
Arcella	6,238±2,431	0±0	0±0	0±0	0±0	0±0
Centropyxis	0±0	0±0	1,331±969	0±0	0±0	0±0
Euglypha	0±0	0±0	517±517	0±0	0±0	0±0
Parundella	0±0	0±0	776±776	0±0	0±0	0±0
Difflugia	0±0	0±0	0±0	2,582±2,582	0±0	0±0
Subtotal	6,238±2,431	0±0	2,615±301	2,582±2,582	0±0	0±0
Monogononta						
Lepadella	835±835	0±0	0±0	0±0	0±0	0±0
Hydrozoa						
Gastroblasta	0±0	0±0	0±0	0±0	0±0	1,455±1,455
Bacteria						
Bacteria	280,20,000 ± 102,61,663	476,60,000 ± 196,87,874	821,48,000± 77,85,075	568,66,667± 128,69,728	705,60,000± 184,90,008	649,60,000± 364,04,082

Different superscript letters in the same row are significantly different at $p<0.05$

Table 5: Periphyton biomass in rice straw in different treatments during experimental period

	Treatments					
Parameters	T2	T3	T4	T5	T6	T7
Dry matter (mg cm^{-2})	0.68 ± 0.10^{a}	0.72 ± 0.02^{a}	0.62 ± 0.04^{a}	0.64 ± 0.03^{a}	0.27 ± 0.02^{b}	0.21 ± 0.03^{b}
Ash free dry matter (mg cm^{-2})	0.42 ± 0.09^{a}	0.49 ± 0.04^{a}	0.45 ± 0.04^{a}	0.45 ± 0.02^{a}	0.19 ± 0.06^{b}	0.16 ± 0.03^{b}
Ash content (%)	38.5 ± 6.25^{a}	31.2 ± 1.02^{ab}	24.5 ± 2.60^{b}	27.6 ± 1.39^{ab}	28.8 ± 4.82^{ab}	22.7 ± 3.29^{b}
Chlorophyll-a (μg cm^{-2})	8.03 ± 0.36^{abc}	9.65 ± 2.38^{a}	7.83 ± 0.18^{abc}	9.13 ± 0.42^{ab}	5.70 ± 1.25^{bc}	5.25 ± 0.50^{c}

Different superscript letters in the same row are significantly different at $p<0.05$

exhibited similar relationship as found by Azim *et al.* (2001), Huchette *et al.* (2000). However, dark brown water colour imparted by dissolved organic matter and by the suspended particulate matter from the decomposing plant matter can not be overruled. Transparency was higher in the treatment T4 which might be the indication of appropriate loading rate of rice straw to clear the turbidity in fertilized tanks.

Plant substrate offer plankton growth (Olaleye and Adedeji , 2005) and plankton density didn't differ significantly among treatments which indicated that periphyton did not affect plankton growth (Azim *et al.*, 2002b; Leghari, 2001). Periphyton biomass was low in high rice straw loading treatments which might be due to lower euphotic layer caused by dense phytoplankton which is reflected in Chlorophyll-a content. Light is the key factor to affect periphyton biomass (Azim *et al.*, 2002a; Van Dam *et al.*, 2002). Bacteria are the prominent microbial group responsible for the decomposition. However, bacteria total plate count number did not vary among treatments.

The water quality was unsafe for fish culture at high rice straw loading treatments. Oxygen susceptible fish like carps are unfit at high rice straw loading rate. Further, periphyton biomass decreased in high rice straw loading treatments. So, it is not wise to increase rice straw loading higher than 0.625 kg ha^{-1}. The loading rate of 625 kg ha^{-1} found to be best among treatments and appropriate for carp culture. Nevertheless, the experiment was carried out in tank without fish, so, effects of decomposition on fish growth and production needs to be assessed in ponds.

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