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Study about the Effect of Rice Straw Mat on Water Quality Parameters, Plankton Production and Mitigation of Clay Turbidity in Earthen Fish Ponds

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Abstract: An experiment was conducted to assess the effect of rice straw mat on the water quality parameters, plankton density, pond water bacterial and mitigation of clay turbidity in fertilized fish ponds at Asian Institute of Technology using five treatments with three replicates. Treatments were: Control (T1); single rice straw mat (T2); two rice straw mats (T3); three rice straw mats (T4) and four rice straw mats (T5). Size of each mat was 5x0.5 m (L x W) that contained 12.5 kg dry rice straw. Mats were placed in water column from equal distance from the dike. Results showed that rice straw significantly decreased the dissolved oxygen level during the early experimental period. Some of the water quality parameters showed significant differences among the treatments. Two mats (25 kg dry straw) was most effective in inhibiting algal growth in 200 m^2 fish pond and hence decreased the fish production, might be due to the release of allelochemicals from rice straw. Total phytoplankton number significantly different among the treatments. The number of Bacillariophyceae, Chlorophyceae, Cyanophyceae, Euglenophyceae was lowest in Treatment 3. Total number of zooplankton was also significantly lower in T3 and among the zooplankton the number of rotifer was found lowest in same treatment. Bacterial load was higher in higher loading rate and the number gradually decreased with the time of culture period. No significant different was found in the number of benthos among the treatments. Mean weight gain and daily weight gain of fish was significantly different among the treatments. Gross yield in Treatment 3 was significantly lower than control. The present experiment indicates that rice straw mat effectively mitigate clay turbidity and 25kg/200 m^2 pond can effectively reduce the population of phytoplankton and zooplankton. This might be due to the synergistic effects of various phenolic compounds released from the rice straw. It is suggested that further research could be done on the type chemicals released from the rice straw and their mode of action on controlling specific plankton in laboratory condition.

Key words: Rice Straw % Water Quality % Phenolic Compound % Plankton % Turbidity % Fish

INTRODUCTION

Successful fish culture depends on the desire water quality parameters for particular fish species as fish pond considered as living dynamics system. Fish production correlated with the water quality parameters [1]. Water chemistry of a pond determines its suitability for fish and deterioration of water quality parameters may harmful for the culture species due to continuous fluctuations in its physicochemical and biological parameters. Sometimes a single component can be dealt with separately due to the complex interaction between the components within the dynamics. That has an impact on growth, survival and production. At the same time pond dynamic depends on the physical exchanges between the ponds and its environment.

The aquaculture systems have been vigorously developed in recent years mainly to serve food security and income generation for the people in developing countries. To satisfy these demands, aquaculture has been undergoing diversification of cultured species and intensification of culture systems. Development of low-cost technologies and their application to current farming practices would help in enhancing aquaculture production.

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Fertilizer is used for increasing algal growth that is common in Asia aquaculture. Beside this, heterotrophic organisms decompose organic matter and release nutrients that can again be utilized by algae or consumed by fish [2, 3]. Though fertilization is normal practice; this practice sometimes may create high phytoplankton blooms and may dominated by noxious algae. Subsequently phytoplankton reduces the light penetration to the lower level of the pond and may create adverse effects on benthic algal mats.

By providing organic matter, heterotrophic food production can be increased several fold and if the substrate assist to grown natural food and more fish should be able to harvest microorganisms directly in significant quantity [3] and if the substrate would mitigate the clay turbidity at the same time, that would support fish production. Provision of plant substrate is therefore being useful for the growth of natural food in the pond.

Bacteria are the primary colonizing organisms at solid-liquid interface and the role of microorganisms is well documented in the nutrient of fish and shellfish [4-8]. Promotion of microbial biofilm on substrates in ponds as an important low-cost strategy to boost the production of warm water fishes that has been demonstrated by various authors [6, 9, 10]. Several types of substrates have been used for the development of bacterial biofilm and periphyton, including easily biodegradable sugarcane bagasse, dried *Eichhornea*, less biodegradable bamboo, [8, 11, 12] and non biodegradable plastic [13], Aqua Mats [14]. Compared with less and non-biodegradable substrates, biodegradable plant substrates providing more fiber and surface area may favor better growth of fish through bacterial biofilm and lead to better results. On the other hand research on open water showed that barley straw is effective for controlling the toxic algae in the open water and laboratory condition [15]. Park *et al*. [16] mentioned that rice straw extract showed allelopathic activity to *Microcystis*. But very few researches have been done to explore the potential of using rice straw to improve water quality, algal control and enhance fish production. It was found that covering pond dikes with rice straw reduced the clay turbidity and enhanced growth of tilapia [17, 18]. Therefore, use of rice straw should be one of the best alternatives option for water quality management and microbial production. It has large potential to be used for controlling water quality, phytoplankton production. However, little research has been conducted to investigate the physical, chemical and biological changes caused by rice straw in fishponds and the optimum-loading rate of rice straw in fishponds. The present study was undertaken to assess the effect of rice straw mats on water quality parameters, phytoplankton production and clay turbidity and to optimize the loading of rice straw mats in fertilized Nile tilapia ponds.

MATERIALS AND METHODS

The experiment was conducted in 15 earthen ponds of 200 m^2 with an average depth of 1.0 m at Asian Institute of Technology, Thailand from November 2005 to March 2006. Prior to starting the experiment, all ponds were drained completely, limed according to soil pH. Ponds were fertilized weekly with urea and triple super phosphate at a rate of 28 kg N and 7 kg P ha^{-1}. Water was added weekly to replace water loss due to seepage and evaporation and maintain the water depth at 1.0 m. Sex- reversed all-male Nile tilapia were stocked at 2 fish m^{-2}. Fish fry were stocked when dissolved oxygen level raised around 3 ppm in each pond.

The experiment was conducted in a completely randomized design There were five treatments with three replicates: (T1) Control (no rice straw); (T2) One rice straw mat of 5x1 m (LxW); (T3) Two rice straw mats of 5x1 m (LxW); (T4) Three rice straw mats of 5x1 m (LxW); (T5) Four rice straw mats of 5x1 m (L x W). Each mat contains 12.5 kg rice straw (dry weight). Mats were made by placing the straw on bamboo frame and tied tightly by iron wire. Vertical and horizontal bamboo splits were used to fix the straw for preparing the mat. Mats were placed in the water column in pond horizontally by using bamboo pole maintaining equal distance from the dike.

Column samples of pond water were taken monthly at 09:00 h from walkways extended to the center of the ponds. Sample were analyzed for 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), chlorophyll-*a*, total suspended solids (TSS) and total volatile solids (TVS) using standard methods. Tannin was determined at the beginning and end of experiment by using colorimetric standard method [19].

Prior to stocking fish dissolved oxygen (DO), pH and temperature were monitored daily at 06:00 h until DO level increase up to 3 ppm.. Biweekly DO, pH, temperature and Secchi disk were measured in situ using YSI model 58, pH meter and Secchi disk respectively at 09.00 h. Monthly dial DO, pH and temperature for each pond were conducted at 06:00, 09:00, 14:00, 16:00, 18:00 and 22:00 h at 25 cm below water surface, middle and 25 cm above the bottom. Monthly plankton samples were taken by using plankton net (No.67 and 15) and identification of plankton were carried out by Bellinger method [20] and APHA [21]. Water sample for bacterial load was collected monthly and total plate counting (TPC) of bacteria was estimated on nutrient agar at room temperature by the spread plate method. To identify the invertebrate fauna of the pond bottom sediment sample were collected by six-inch-square Ekman dredge [21]. Two samples from each pond were taken monthly and were washed over a Standard U.S. No. 30 (0.595 mm) sieve. The sample were identified by using stereoscope and counted the number of organism in each group. The data were analyzed for significant differences among treatments using one-way analysis of variance (ANOVA) using SPSS statistical software package. Differences among treatments were considered significant at an alpha level of 0.05. All means were giving with ± standard error (SE).

RESULTS

The results indicated that mean survival rate of Nile tilapia ranged from 75.6 to 84.4%. The highest survival rate was observed in T1 and the lowest was in T2. The Mean weight gain and daily weight gain of fishes were significantly different among the treatments. The highest gross yield was observed in control and lowest was observed in T3 that was significantly different than control (Table 1).

Dissolved oxygen (DO), pH and temperature in early morning (0600 h) were monitored every day before stoking fish in pond. The dissolved oxygen level decreased after one week of placing rice straw mat in the pond. In treatment 4 and 5 it was decreased up to 0.5 mg L^{-1}. The lowest mean of DO was observed in T5. DO level in all ponds reached above 2 mg L^{-1} after 35 days of placing mat in the pond. The mean pH level during preliminary monitoring period varied from 7.5±0.1 to 7.8±0.1. The average temperature ranged from 27.8 to 28.6°C (Table 2).

The water quality parameters measured biweekly and monthly during the experimental period are summarized in Table 3. The DO concentration at 0900 h ranged from 4.0 to 5.8 mg L^{-1}, pH 7.6 to 8.3 and temperature 27.1 to 27.6°C throughout the experiment (Table 3). Mean total alkalinity in different treatments ranged from 112.27±6.4 to 132.8±14.56 mg L^{-1}. The lowest mean average value of total Kjeldahl nitrogen was observed in T3 (6.75±0.2). Mean total phosphorus ranged from 0.27 to 0.72 mg L^{-1} during the experimental period. The lowest TP concentration was recorded in T3 that was significantly different than control. Mean soluble reactive phosphorus concentration ranged from 0.043±0.026 to 0.19±0.15 mg L^{-1} and the lowest was observed in T3. Total ammonia nitrogen recorded in T3 was significantly higher than control (P>0.05).

Secchi disc visibility decreased towards the end of the culture period and the lowest mean value was recorded in the Treatment 1 and 2. Treatment 1 showed highest chlorophyll-*a* concentration (412.87±83.9) where as the lowest value was recorded in treatment 3 (63.51±5.73). Mean chlorophyll-*a* concentration in Treatment 2 and 3 were significantly (P<0.05) different than control. Treatment 3 had the lowest TSS and TVS concentration during the experiment. Mean values of TSS and TVS in different treatments during the experimental period were ranged from 59.33 to 131.00 mg L^{-1} and 31.3 to 54.3 mg L^{-1}, respectively. Mean tannin

Table 1: Growth performance of Nile tilapia cultured in different treatments

Parameters	Treatment 1(T1)	Treatment 2(T2)	Treatment 3(T3)	Treatment 4(T4)	Treatment 5(T5)
Stocking					
Mean weight (g fish^{-1})	26.65±0.22	22.19±2.3	24.24±2.5	26.30±0.7	23.65±2.3
Total weight (kg pond^{-1})	10.66±0.1	8.87±0.9	9.70±1.0	10.52±0.3	9.46±0.9
Harvest					
Mean weight (g fish^{-1})	132.77±1.7^{b}	103.17±15.6^{ab}	82.5±3.3^{a}	119.73±13.4^{b}	132.77±4.0^{b}
Total weight (kg pond^{-1})	44.73±2.0	32.57±9.2	26.27±1.5	40.2±5.1	43.5±1.7
Survival rate (%)	84.37±4.4	75.6±11.5	79.43±1.5	83.67±2.2	81.87±1.7
Daily weight gain	0.91± 0.02^{b}	0.69±0.11^{ab}	0.5±0.04^{a}	0.80±0.11^{b}	0.93±0.05^{b}
Mean weight gain (g fish^{-1})	106.09±2.5^{b}	80.99±14.0^{ab}	58.26±4.7^{a}	93.46±12.7^{b}	109.13±5.9^{b}
SGR (%)	1.37±0.0^{b}	1.30±0.1^{ab}	1.06±0.1^{a}	1.29±0.1^{a}	1.48±0.1^{b}
Gross yield (ton ha^{-1} year^{-1})	6.97±0.3^{b}	5.1±1.4^{ab}	4.07±0.2^{a}	6.3±0.8^{a}	6.77±0.3^{b}
Net yield (ton^{-1} ha^{-1} year)	5.33±0.3^{b}	3.67±1.3^{ab}	2.57±0.3^{a}	4.63±0.8^{ab}	5.3±0.3^{b}

Values are mean ± SE (n=3), mean values with different superscript letters in the same row were significantly different (P<0.05)

Table 2: Mean values of DO, pH and temperature measured daily at 0600h during pre-stocking period

Parameters	Treatment 1(T1)	Treatment 2(T2)	Treatment 3(T3)	Treatment 4(T4)	Treatment 5(T5)
Mean value					
Temperature (^{0}C)	28.34±0.15	28.51±0.15	28.26±0.14	27.98±0.10	28.29±0.06
DO (mg L^{-1})	3.83±0.17	3.32±0.90	2.87±0.32	1.85±0.06	1.45±0.47
pH	7.67±0.03	7.80±0.08	7.65±0.11	7.48±0.05	7.58±0.06

Values are mean ± SE (n=3); and significant difference (P<0.05)

Table 3: Summary of mean values of water quality parameters measured at 0900h during the experimental period

Parameters	Treatment 1(T1)	Treatment (T2)	Treatment 3 (T3)	Treatment 4(T4)	Treatment 5(T5)
Mean value					
Temperature (^{0}C)	27.17±0.15	27.40±0.30	27.60±0.10	27.20±0.30	27.53±0.12
DO (mg L^{-1}) (0600 hr)	3.07±0.36	2.56±0.33	2.48±0.07	2.38±0.25	2.18±0.29
DO (mg L^{-1}) (0900 hr)	5.87±0.22	4.63±0.75	4.03±0.24	4.63±0.54	4.60±0.61
pH	8.33±0.28	8.00±0.17	7.63±0.12	7.93±0.27	7.97±0.17
Transparency (cm)	18.43±0.24	25.67±5.77	26.93±1.65	27.47±8.47	23.03±2.49
Alkalinity (mg L^{-1})	132.8±14.56	112.2±6.47	127.93±9.97	126.6±5.86	128.2±11.32
TAN (mg L^{-1})	0.88±0.13	1.13±0.10	1.49±0.23	1.28±0.13	1.49±0.31
NO_3-N (mg L^{-1})	0.52±0.0.09	0.60±0.09	0.65±0.03	0.45±0.04	0.42±0.02
NO_2-N (mg L^{-1})	0.15±0.07	0.13±0.04	0.16±0.03	0.09±0.03	0.08±0.01
TKN (mg L^{-1})	7.63±0.51^b	7.01±1.19^{ab}	6.75±0.2^a	9.01±1.02^{ab}	8.0±0.63^{ab}
TP (mg L^{-1})	0.72±0.18^b	0.72±.0.16^{ab}	0.27±0.02^a	0.54±0.10^{ab}	0.47±0.07^{ab}
SRP	0.19±0.15	0.087±0.063	0.043±0.026	0.053±0.03	0.073±0.02
TSS (mg L^{-1})	117.0±18.15	131.0±65.87	59.33±6.36	121.33±31.1	72.67±17.3
TVS (mg L^{-1})	54.33±1.76	49.33±13.78	31.33±0.33	48.67±8.37	41.00±5.51
Chlo-*a* (mg m^{-3})	412.87±83.9^b	93.78±37.17^a	63.51±5.73^a	261.1±113.8^{ab}	225.57±85.3^{ab}
Tannin (mg L^{-1})	5.32±0.14	6.82±0.97	7.12±0.75	5.41±0.10	6.41±0.36

Values are mean ± SE (n=3), mean values with different superscript letters in the same row were significantly different (P<0.05)

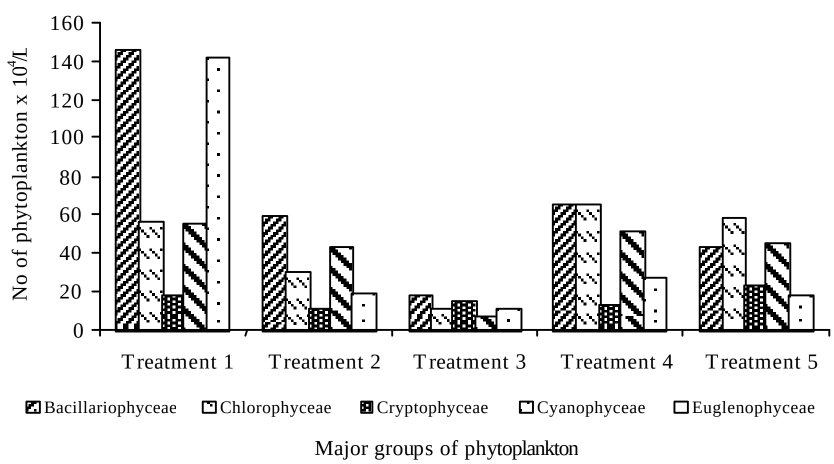

Fig. 1: Major groups of phytoplankton in different treatments during the experimental period

concentration ranged from 5.32±0.14 to 7.12±0.75 mg L^{-1}. The lowest tannin concentration was found in control and highest was in Treatment 3.

Phytoplankton were identified and counted as cell, filament or colonies per liter of pond water. The mean phytoplankton number ranged from 4158960 to 613020. The average number of phytoplankton was significantly different among the treatments. T2 and T3 were significantly lower than the control (P<0.05). Phytoplankton identified during the study comprised of 87 genera belonging to Bacillariophyceae (20 genera), Chlorophyceae (38 genera), Chrysophyceae (4 genera), Cryptophyceae (6 genera), Cyanophyceae (13 genera), Euglenophyceae (4 genera) and Xenthophyceae (1 genera)). The total number of phytoplankton increased with progress of experimental period in all treatments, except Treatment 3. The major groups of phytoplankton varied in different treatments.

Table 4: Abundance of phytoplankton and zooplankton (cell, filament or colonies L^{-1}) in pond water during the experimental period

Group/Genus	Treatment 1(T1)	Treatment 2(T2)	Treatment 3(T3)	Treatment 4(T4)	Treatment 5(T5)
Phytoplankton					
Average No of Phytoplankton	4154920 ±870171^{b}	1612460 ±1065369^{a}	613020.±48581^{a}	2224520±944644^{ab}	1867106±547263^{ab}
Bacillariophyceae	1460140±1019161	592133±521832	174673±21740	655447±364249	422287±199243
Chlorophyceae	554273±81078	304387±187073	111527±13317	651613±324953	584993±210035
Chrysophyceae	333±333	00±00	3533±3533	333±333	5600±5600
Cryptophyceae	181093±59688	103347±60610	154920±32150	133113±98288	232667±66834
Cyanophyceae	547653±195812	427213±308255	61040±24574	514407±227671	449900±228786
Euglenophyceae	1411093±1127908	185380±488867	107327±37072	268273±100100	171660±39029
Xanthophyceae	333±333	0±0	0±0	1333±882	0±0
Zooplankton					
Average No of Zooplankton	17180±2161^{b}	11717±3487^{ab}	7418±1145^{a}	136423±3994^{ab}	10385±384^{ab}
Crustacea	4773±905	5058±1046	5653±969	3815±728	5123±990
Rotifera	9040±3356	5775±2399	1315±254	8460±2723	4283±1298
Ciliata	1183±933	175±88	275±159	92±92	450±247
Sarcodina	260±152	92±92	92±92	00±00	83±83
Monogononta	1832±326	617±385	83±83	965±488	353±221
Hydrozoa	0±0	0±0	0±0	92±92	92±92

Values are mean ± SE (n=3), mean values with different superscript letters in the same row were significantly different ($P<0.05$)

Table 5: Mean value of bacteria (ml^{-1} water) and benthos (m^{-2} bottom area) in different treatments

Parameter	Treatment 1(T1)	Treatment 2(T2)	Treatment 3(T3)	Treatment 4(T4)	Treatment 5(T5)
Bacteria					
Average	1905.0±193.4	1737.7±288.7	1699.3±464.7	2058.3±174.2	4140.0±1078.4
Benthos					
Average	531.3±238.6	1001.3±59.40	499.0±35.81	728.7±245.77	795.0±205.61
Groups					
Oligochaete	368.0±203.6	737.7±34.48	298.0±11.59	561.3±185.25	664.0±248.38
Chironomids	141.7±57.5	163.7±28.7	55.7±7.8	88.0±59.5	59.3±21.7
Mollusks	21.7±6.1^{a}	95.3±9.4^{ac}	143.7±31.4^{bc}	73.7±9.9^{ac}	68.3±27.8^{ac}
Crustacean	0.0±0.0	5.0±0.0	1.7±1.7	5.3±5.3	3.3±1.7

Values are mean ± SE (n=3), mean values with different superscript letters in the same row were significantly different ($P<0.05$)

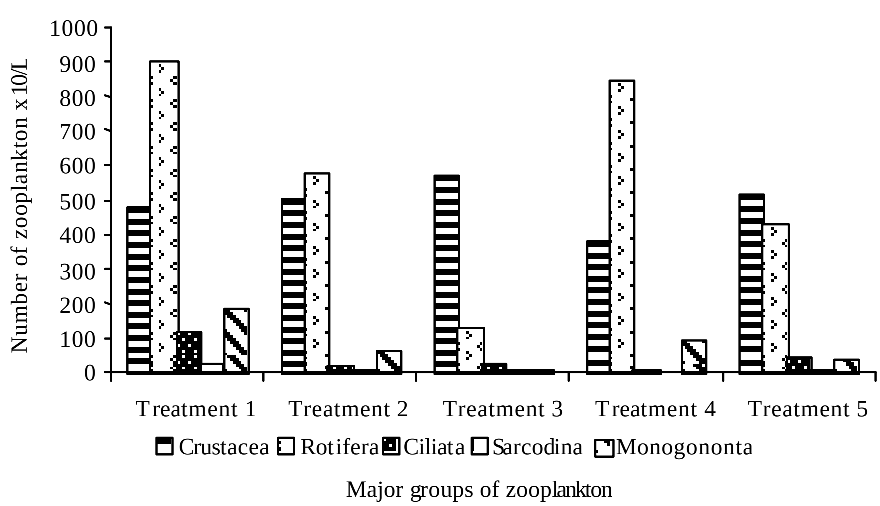

Fig. 2: Major groups of zooplankton in different treatments during the experimental period

Bacillariophyceae and Euglenophyceae were the dominant in control. Lowest number of total phytoplankton number was observed in T3 as well as Bacillariophyceae, Cholrophyceae, Cyanophyceae, Euglenophycease (Table 4, Figure 1). From the research it was observed that rice straw can effectively control phytoplankton production and Treatment 3 (25 kg dry straw) was most effective in inhibiting algal growth in 200 m^2 fish pond.

Zooplankton comprised of 23 genera belonging to Crustacean (6 genera), Rotifera (8 genera) Ciliata (4 genera), Sarcodina (2 genera), Monogononta (1 genera) and Hydrozoa (1 genera) (Table 4). T1 showed the highest number of zooplankton and the lowest was observed in T3. Among different groups of zooplankton Rotifera Ciliata, Sarcodina and Monogononta showed highest in treatment 1 whereas the number of crustacean was highest in T3 and lowest number of rotifer was observed in the same treatment (Figure 2). The average number of zooplankton was significantly lower than control ($P<0.05$).

Total plate count of bacteria showed that highest bacterial count was found in T5. The mean value of bacterial count in different treatments ranged from 1699.33 to 4140.00 (Table 5). The lowest number was recorded in T3. Mean and final number of benthos per meter square bottom area was summarized in Table 5. Among different groups of benthos Oligochaete showed highest number in all treatments without any significant differences among the treatments.

DISCUSSION

The present study indicated that 25 kg dry rice straw did not result in significant improved growth performance of tilapia. Treatment 3 showed strong performance in controlling algal growth. This might be due the inhibitory effect of rice straw on phytoplankton and zooplankton in the pond ecosystem. Because rice straw might release phenolic compounds that have a synergistic effect on growth of plankton production. Also at this concentration these phenolic compounds might have negative effects on the fish growth. However, this effect is not the same for higher loading rate. It was reported that *Microcytic* was effectively inhibited with a low concentration (0•01 mg LG^1) of a rice straw extract in natural water [16] and the number of cells significantly decreased compare to control. Similar results were found by using barley straw on micro-algae [22-26]. However, none of the author did not assess the effect of rice straw on zooplankton and fish production and the suitable concentration of phenolic compounds released from rice straw or barley straw in fish culture pond. Gad and Saad [27] reported that phenol and its derivatives induced toxic effect for fishes. They also mentioned that 0.7 mg/L can decreased the growth performance of Nile tilapia and accumulation of phenol were detected in the fish liver, muscle and gills.

In all the treatments tilapia survival rate was high (>75%). In tank experiment with paddy straw and sugarcane bagasse as substrate, Mridula *et al.* [6] reported 78.67 and 70.67% survival for *Labeo rohita*. However, the author did not mentioned about the synergistic effect of rice straw on water quality parameters.

Rapid decrease in dissolved oxygen level was recorded in all the ponds after placing rice straw mat(s) in the pond and it took around one month to recover DO to the suitable level for fish stocking. This can be attributed to the increased biological oxygen demand in water with predominantly heterotrophic food production which accounts for bulk of the oxygen consumption [2]. Mridula *et al.* [28] also observed that application of plant materials affects water quality; mainly dissolve oxygen in the beginning. In this study, pH was slightly alkaline in all of the ponds during the pre stocking period, indicating favorable conditions for biological production. Similar results have been reported by Ramesh *et al.* [29].

It was found that loading rate of 25 kg dry rice straw in the pond showed significant difference in some of the water quality parameters. Rice *et al*. [30] found that five phenolic inhibitors were released from the decomposition of rice straw that have negative impact on water quality parameters as well as oxygen uptake. It was also reported that substances from biomaterials can act as a biological control in the ecosystem [31, 32]. The present research also showed the similar indication and that might be due to the release of different allelochemicals and phenolic compounds at different concentration that promotes high synergistic effect on water quality parameters. Moreover, decomposition of straw was uptake oxygen from the pond ecosystem. Study on the effect of Aqua Mats on growth of Nile tilapia showed that use of Aqua Mats did not effectively improve water quality parameters and fish production was not significantly increased [14]. In this experiment water quality parameters showed significant changes in T3, however as the dissolved oxygen and pH was within the limit during that is why no mortality of fishes were observed.

In this study, control had the highest number of phytoplankton among all the treatments. Total phytoplankton genera identified in this study was 87, which are similar to the statement of Azim [4] and Manikannan *et al*. [33]. High chlorophyll-*a* concentration and subsequently, high phytoplankton number as well as increasing trends over the experimental period that created thick phytoplankton layer on the water surface in T1. Excess phytoplankton bloom may crease unfavorable environment fish culture. The Chlorophyll-*a* concentration was highest in control and was lowest Chlorophyll-*a* in T3. This might be due to the inhabitation of phytoplankton growth by chemical released from rice straw.

It was found that barley straw extract was found to effectively inhibit the growth of several planktonic and filamentous algae in the laboratory experiment and reservoirs [23, 24]. The allelochemicals released from barley and rice straw limits the germination, growth, photosynthesis, respiration and metabolism of other planktons [31, 32, 34]. Thus, the phenolic compounds in rice straw may inhibit the growth of planktons in pond environment.

Some research on barley straw showed that decomposing straw produces chemical substances that effectively inhibit the growth of some nuisance cyanobacterial species [24, 35-37]. The accurate chemicals of barley straw that control the cyanobacterial growth have not been clearly recognized, but limited research suggested that oxidized phenolics, or free radicals from their decomposition are the inhibitors [38-40]. Other researcher reported that the phenolic compounds in rice are also very similar to those in barley [31].

In the control pond Bacillariophyceae and Euglenophyceae were the most dominant group of phytoplankton. On the other hand major groups of phytoplankton were lowest in T3. However, this result disagrees with statement of Mridula *et al.* [6] who reported that using paddy straw and sugarcane bagasse in tank with *Labeo rohita* resulted in higher numbers of Cyanophyceae and Chlorphyceae. However the author did not discuss about the loading rate and phenolic compound that might release from the straw or biodegradable products. It was reported that combination of different compounds rather than specific concentration of single compound was more effective in inhibiting the growth and nitrogen fixation, indicating a synergistic effect [30]. Another research finding showed that many allelochemicals at low concentrations in rice straw probably promotes a high synergistic effect on growth inhibition of plankton [16].

Total number of zooplankton was significantly lower in Treatment 3 than control. Among the different groups of zooplankton the number of rotifer was found lowest in Treatment 3. Though Radhakrishnan and Sugumaran [41] mentioned that use of sugarcane bagasse as artificial substrate in the tank increased the zooplankton number. From the present study it can be concluded that rice straw might release the phenolic compounds in the ecosystem that inhibit the plankton growth in pond environment and the concentration of compounds released from 25 kg dry straw in 200 m^2 ponds was most effective in controlling plankton and clay turbidity.

The total plate count of bacteria in water increased at the beginning and declined gradually at the end of the experiment. Though mean TPC in water did not differ significantly among different treatments, a higher bacterial count was observed in the Treatment 5. In this experiment the mean bacterial load varies from 1.9×10^3 to 4.1×10^3, which was higher than the bacterial load (0.75×10^4 CFU ml^{-1}) reported earlier in paddy straw tanks [6]. However, heterotrophic bacterial load in brackish water pond varies from 6.0×10^2 to 1.0×10^4 CFU ml^{-1} water [42]. The reduction in density of bacterial biofilm, phytoplankton and zooplankton towards the end of experiment might have slowed down Nile tilapia growth in the present study. And the decrease in bacterial count towards the end of the experiment might be related to the unavailability of the biodegradable substrate which decomposed during the experiment. It was also reported earlier that the biodegradable substrate increased bacterial biofilm, however, bacterial activity was dependent on the types of organic matter, loading rate and season [43, 44].

Among the four different groups of benthic invertebrates, Oligochaete was the most dominant group. The diversity of benthic groups observed in this study is similar to the report of Kelly and Kawes [45]. The result of the present study indicated that rice straw loading had positive effect on the growth of benthic organisms. Study on the effect of different substrates on growth and productivity of earthworm showed that cellulose substrate was the best culture media for earthworm [46]. In the present study no mortality of benthic organisms were observed in all treatments probably because dissolved oxygen never went down below the critical level. The result suggests that the decrease in benthos number towards the end of the experiment might be caused by fish grazing and it was reported that production of all organisms, autotrophic and heterotrophic, pelagic and benthic were directly used by fish [34]. However, future study could be done on the type chemicals released from the rice straw and their mode of action on controlling specific plankton in laboratory condition.

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