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Influence of Soil on Biodegradation of Organic Wastes and Production of Live Fish Food Organisms

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Abstract

In the biodegradation process, role of soil in waste treatment was evaluated. For this purpose, 50% domestic sewage, 750 mg l^{-1} sewage sludge and 500 mg l^{-1} night soil were selected for treatment. Each of these treatments was inoculated with four brooders of cladoceran for their multiplication and their subsequent performance was assessed for a period of 30 days. Presence of soil definitely increased the production of cladoceran. As such, the highest (5600 l^{-1}) cladoceran population was noticed in culture systems having soil bed and treated with domestic sewage while the lowest (20 l^{-1}) being in control. The results have depicted significant role of soil in maintaining favourable water quality conditions for good aquaculture. The concentration of organic carbon, phosphorus, nitrate-nitrogen and ammonia-nitrogen reduced significantly ($p < 0.05$) in each culture medium from the initial levels. The study suggests that soil could be used in live fish food culture system that is helpful in waste recycling.

Keywords: Aquaculture, biodegradation, cladoceran, live fish food, waste recycling

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Introduction

There is a general agreement that significant increase in fish yield, following the successful use of fertilizers, is due to the growth of plankton and the transformation of plankton into fish flesh through food web of an aquatic ecosystem. Schroeder (1974) and Boyd (1979) have categorically emphasized the importance of pond fertilization in aquaculture. In fish ponds, the natural food production mainly depends upon the availability of essential nutrients and thus soil is the main source of these elements (Ayyappan, 1991). The physico-chemical properties of soil influence the quality of water and accelerate the various production processes in fish ponds. The mineralization of organic wastes and production of plant nutrient are the primary functions of decomposition (Ayyappan, 1991). The degradation of organic waste controls a number of functions in aquatic ecosystem like recycling of nutrients through mineralization of organic matter by microbes. The role of soil bed in augmenting zooplankton production has been evidenced by the earlier researches (Sharma, 1985). It has also stated that soil, provides a substratum for the growth of microbes and later these microbes are consumed by filter feeder zooplankton supporting secondary production without the development of usual phytoplankton-zooplankton food chain. In view of this, the present investigation on the role of soil bed in cladoceran culture in waste treated waters was designed specially to understand the role of soil and associated bacteria in aquaculture. This study also aimed at evaluating the role of soil in stimulating process of waste recycling for the production of cladocerans with reference to particular water quality.

Materials and Methods

Two sets of glass aquaria (*viz*., one with soil bed and another without soil bed) were used for evaluating the impact of soil bed on cladoceran production. In one set of 8 glass aquaria, 5 cm soil bed was provided whereas, another set was used without soil bed. After filling with filtered well water, each glass aquarium was fertilized with organic waste. Based on the preliminary experiments, the optimum dose of each waste *viz.,* domestic sewage, sewage sludge and night soil was arrived at. Accordingly, doses of different treatments and their application details are given in Table 1.

To have sufficient seed of cladocerans for growth and multiplication, each treatment was inoculated with four brooders of cladocerans collected from the stock culture which was maintained in the laboratory. After fertilization on initial day, water samples were collected for the analysis of selected physico-chemical and biological parameters.

Table 1. Different treatment types of organic wastes

Without soil bed		With soil bed	
Treatments	Organic Waste & Doses	Treatments	Organic Waste & Doses
C_1	Control	C_1	Control
DS_0	Domestic sewage @ 50%	DS_1	Domestic sewage @ 50%
SS_0	Sewage sludge @ 750 mg l^{-1}	SS_1	Sewage sludge @ 750 mg l^{-1}
NS_0	Night soil @ 500 mg l^{-1}	NS_1	Night soil @ 500 mg l^{-1}

The population of cladocerans was counted in each of the experimental and control tank at 5, 10, 15, 20, 25 and 30 day. The quantitative analyses of cladocerans were done with a Sedgwick Rafter Cell (Pennak, 1978). The water quality of the experimental media was examined first after fertilization and subsequently at 5 days interval up to 30 day period. The temperature and dissolved oxygen (DO) were measured using a DO meter (HACH HQ10 model) and pH with a digital pH meter (HACH). The total phosphorus, orthophosphate, nitrate nitrogen, ammonia nitrogen and organic carbon were analyzed following standard methods (APHA, 1989). The total bacterial population (Standard Plate Count - SPC) was also tested in each of the tank at 5 days intervals following WHO (1984) and APHA (1989). The soil samples were collected initially and subsequently at 10 days interval for the analysis of pH, organic carbon, available phosphorus and available nitrogen. The samples of soil were analysed as per Pipper (1950). Analyses of Variance (Steel & Torrie, 1982) were performed for testing statistical significance of the results.

Results and Discussion

The results of the present investigation pertaining to the physico-chemical parameters are presented in Tables 2, 3, 5 and biological parameters in Fig. 1, Table 4, 6. The dissolved oxygen ranged between 1.28 and 12.50 mg l^{-1} with the highest (12.50 mg l^{-1}) in DS_o and the lowest (1.28 mg l^{-1}) in DS_1.

The data on organic carbon (Table 2) suggest that the application of soil did not influence this ingredient to an appreciable extent. In general, the organic carbon in different experimental waters ranged between 0.35 and 10.05 mg l^{-1}, the highest being in DS_1 and the lowest in C_o. The average values of NO_3-N ranged from 1.38 to 0.25 mg l^{-1} with highest and lowest being in DS_1 and C_o respectively. Similarly, the highest (0.46 mg l^{-1}) and the lowest (0.08 mg l^{-1}) average value of NH_4-N were also in DS_1 and C_o respectively. In the experimental waters, soil treated waters maintained slightly higher orthophosphate levels than those without soil.

The lowest limit of dissolved oxygen in warm water ponds for good production has been suggested to be 5.0 ppm (Dandroff & Dean, 1967). In the present study, the average values of dissolved oxygen were above this level in both the sets (*viz.*, with and without soil bed) which could be considered favourable for the growth of aquatic organisms (Table 2). Moreover, the dissolved oxygen levels were higher in the treatments without soil bed than with soil bed except in the case of night soil treatment. Comparatively lower values of dissolved oxygen in the treatments with soil bed can be assigned to greater decomposition activities which resulted in a higher biological production. Naturally bacteria were the viable agents for biological degradation (Fig.1). Jana et al. (1980) have reported similar results.

In both the sets of experiments, pH fluctuations were narrow but always remained alkaline (Table 2). Importance of slightly alkaline pH on productivity has been emphasized by Nees (1949). Thus, the prevailing alkaline pH (Table 2) of experimental waters might have favoured a higher population of cladocerans especially in treatments with soil bed.

Table 2. Range and mean (in parenthesis) values of water quality parameters in experimental waters

Parameters	Treatments							
	C_0	C_1	DS_0	DS_1	SS_0	SS_1	NS_0	NS_1
Water Temp.(^{0}C)	17.2-20.3 (18.70)	18.0-20.5 (19.32)	16.5-21.4 (18.95)	18.2-21.0 (19.47)	18.1-20.1 (19.20)	19.0-20.2 (19.44)	18.2-20.6 (18.94)	18.7-20.5 (19.30)
pH	7.9-8.3 (8.10)	7.8-8.4 (8.05)	7.6-8.1 (7.85)	7.5-8.3 (7.77)	7.6-8.1 (7.74)	7.6-8.2 (7.78)	7.6-8.0 (7.75)	7.6-8.1 (7.77)
Dissolved oxygen (mg l^{-1})	8.40-12.00 (10.28)	7.65-10.00 (8.95)	1.75-12.50 (6.05)	1.28-12.25 (5.92)	6.37-10.50 (7.47)	4.25-8.64 (6.48)	5.95-8.50 (6.88)	5.70-9.64 (7.24)
Nitrate nitrogen (mg l^{-1})	0.13-0.31 (0.25)	0.15-0.36 (0.26)	0.28-2.96 (1.37)	0.31-3.14 (1.38)	0.22-0.47 (0.34)	0.29-0.64 (0.40)	0.21-0.48 (0.29)	0.19-0.43 (0.31)
Ammonia (mg l^{-1})	0.00-0.19 (0.08)	0.00-0.32 (0.12)	0.00-1.31 (0.27)	0.06-2.20 (0.46)	0.00-0.34 (0.10)	0.00-0.40 (0.13)	0.01-0.27 (0.12)	0.02-0.23 (0.12)
Orthophosphate (mg l^{-1})	0.00-0.22 (0.12)	0.09-0.26 (0.16)	0.15-1.65 (0.60)	0.28-1.88 (0.64)	0.19-0.65 (0.40)	0.23-0.52 (0.38)	0.17-0.27 (0.22)	0.18-0.29 (0.21)
Total phosphorus (mg l^{-1})	0.69-1.22 (0.90)	0.62-1.30 (0.91)	1.65-7.40 (5.50)	1.72-8.60 (5.84)	1.54-6.05 (1.53)	2.00-5.90 (3.71)	1.52-5.40 (3.30)	1.69-6.20 (3.42)
Organic carbon (mg l^{-1})	0.35-1.09 (0.78)	0.48-1.12 (0.83)	4.20-9.30 (6.35)	3.92-10.05 (6.15)	1.67-2.93 (2.25)	1.56-2.73 (1.97)	1.60-2.42 (2.05)	1.75-2.47 (2.09)

Further, the soil pH also remained slightly alkaline (Table 4) which may be considered favourable for good aquaculture (Chattopadhyay & Mandal, 1982). Soil bed probably also influenced higher decline in pH which may be accounted to more decomposition activities. The higher decomposition rate of organic matter in treated waters is said to release some organic acids which decreases the soil pH.

Both NO_3-N and NH_4-N failed to indicate any definite trend except for the fact that these ingredients showed higher average values in the waste treated waters (Table 2) which might be due to the addition of organic waste. Robert et al. (1992), while studying the occurrence of nitrogen in fish ponds have noticed that organic matter available in water is broken down by bacterial action and the end product of decomposition among others is ammonia. Later ammonia is converted to nitrate through the process of bacterial nitrification. In the present case, as against no soil bed, a higher bacterial population was found in treatments with soil bed which might have advanced the decomposition of organic matter (Table 4). This has resulted in greater inputs of nitrate-nitrogen for its rapid utilization in the aquatic production (Yusoff & Sharr, 1987; Robert et al., 1992). Probably on this account NO_3-N failed to depict a definite trend in the treated waters in the present study. Like NO_3-N, orthophosphate and total phosphorus also exhibited irregular fluctuations in both the sets (*viz*., with and without soil) of experiment (Table 2). However, slightly higher mean values of both these parameters in the treatments with soil bed (Table 2) indicated a higher nutrient status in the waters with soil. Further, the lower values of organic carbon also justify the increased mineralization by bacteria in these treatments, thereby increasing the phosphorus of water (Cole, 1979; Jhingran, 1988).

Based on initial and final values for different water quality parameters, percentage increase or decrease has been calculated (Table 3). Water temperature and pH increased marginally from 1.05 to 5.55% and 1.25 to 7.89% respectively. The dissolved oxygen however, remained unchanged in C_0, while the highest increase of 665.62% was recorded in DS_1 followed by DS_o (474.28%). The lowest increase 2.12% was observed in C_1. NO_3-N, NH_4-N, orthophosphate, total phosphorus and organic carbon were observed to decrease in all the treatments (Table 3). Moreover, percentage reduction in most water quality parameters (Table 3) was higher in the treatments with soil. This further suggests a better utilization of nutrients in these waters together with higher biological production (Jena et al., 2010). The higher percent reduction of total phosphorus may be due to its use by the cladocerans (Hayes &

Table 3. Percent increase (+ve) or decrease (-ve) in values of water quality parameters in experimental waters

Parameters	Treatments							
	C_0	C_1	DS_0	DS_1	SS_0	SS_1	NS_0	NS_1
Water Temp	+5.14	+5.55	+1.05	+2.11	+4.34	+0.52	+1.64	+3.20
pH	+2.46	+1.25	+6.57	+6.66	+1.29	+7.89	+5.26	+5.26
Dissolved oxygen	0.00	+2.12	+474.28	+665.6	+62.79	+50.26	+24.26	+69.12
Nitrate nitrogen	-45.16	-58.33	-90.54	-90.12	-21.62	-8.10	-54.16	-55.81
Ammonia	-100.00	-100.00	-100.00	-97.27	-100.00	-100.00	-91.66	-85.71
Orthophosphate	-87.50	-59.09	-90.90	-85.10	-47.71	-45.23	-34.61	-37.93
Total phosphorus	-41.80	-48.46	-50.67	-56.74	-70.38	-60.00	-71.85	-72.74
Organic carbon	-67.88	-54.71	-54.83	-60.99	-42.80	-43.22	-16.45	-13.36
SPC	-58.26	-49.64	-66.01	-55.62	-67.80	-56.85	-64.24	-63.34

Table 4. Total bacterial population (No. ml^{-1} x 10^5) in treatments with and without soil

Days	Treatments							
	C_0	C_1	DS_0	DS_1	SS_0	SS_1	NS_0	NS_1
0	1.27	1.39	4.09	4.62	3.51	3.50	3.58	3.71
5	1.19	1.25	5.11	5.95	3.33	3.52	3.61	3.78
10	1.10	1.13	3.79	4.05	4.00	4.33	4.16	4.40
15	0.84	0.97	1.96	2.31	2.63	2.68	2.07	2.58
20	0.71	0.74	2.00	1.95	1.42	1.53	1.56	1.55
25	0.76	0.72	1.64	2.48	1.49	1.45	1.84	1.97
30	0.53	0.70	1.39	2.05	1.13	1.51	1.28	1.36

Phillips, 1958; Cole, 1979). In both the sets of experiments, organic carbon and total bacterial population (SPC) showed notable relationship. Initially, organic carbon and SPC were more or less at the same levels in both the sets of experiment. However, higher loss of organic carbon was noticed in treatments with soil bed (Table 3), but the loss in bacterial population was low. A faster decomposition of organic matter released enough organic carbon for equally faster utilization for a high bacterial production, hence higher loss of organic carbon in soil (Pillai, 1959; Arceivala et al., 1970). Higher SPC in treatments with soil bed may be due to the availability of nutrients (including micronutrients) and substratum, which are desirable for multiplication of bacterial flora.

The total bacterial population (SPC) in waste treated waters is presented in Table 4. It is evident that highest SPC (5.95 $Noml^{-1}$ x 10^5) was in DS_1. The decline in bacterial counts was appreciably high in SS_o (67.80%) followed by DS_o (66.01%) and the lowest in C_1 (49.64%).

Initially the values of soil pH were higher in all the treatments which decreased subsequently (Table 5). In general, soil pH ranged from 8.1 to 8.4. Further, organic carbon in the soil ranged from 0.43 to 0.59%. The available phosphorus of soil were found to vary between 0.28 and 0.59%; the lowest and the highest were recorded in C_1 and NS_1 respectively. Moreover, available nitrogen content of experimental soil was the highest (0.23%) in NS_1 and the lowest (0.10%) in DS_1.

Cladoceran population in experimental waters treated with organic wastes with and without soil bed is depicted in Table 6. The highest (5600 no. l^{-1}) cladoceran population was in DS_1, while the lowest (20 no. l^{-1}) was being in control (Fig. 1). From

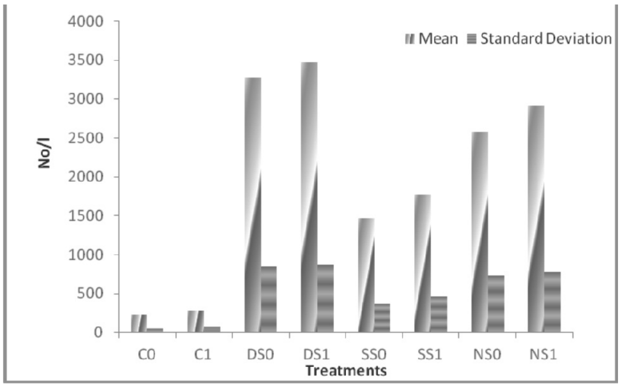

Fig. 1. Mean cladoceran population in different treatments

the average standing crop of cladocerans, the impact of soil in augmenting production of this zooplankton is self evident. The highest average cladoceran population (3436 no. l^{-1}) was in DS_1 followed by DS_o (3273 no. l^{-1}), NS_1 (2918 no. l^{-1}), NS_O (2742 no. l^{-1}), SS_1 (1772 no. l^{-1}) and SS_o (1466 no. l^{-1}). The lowest average density (226 no. l^{-1}) was recorded in C_o.

As depicted in results, the cladoceran population was high in waste treated waters than their respective controls. Here, this population increase was obviously due to increased availability of different nutrients, owing to application of organic wastes (Sharma & Saini, 1992).

Cladoceran population has also justified significantly higher ($p<0.5$) population in treated waters compared to their respective control. Treatments with soil bed maintained higher population of cladocerans which also coincided with the higher bacterial load and nutrient status. A relationship between cladocerans and bacterial population has also been stated earlier (Schroeder, 1978; Shirgur & Siddham, 1988; Saini & Sharma, 2011). Higher amount of nutrients led to better biological production in the present study too, which supports the findings of Smyly & Collins (1975) and Schroeder (1978).

Table 5. Range and mean (in parenthesis) values of soil quality parameters in different treatments

Parameters	Treatments			
	C_1	DS_1	SS_1	NS_1
pH	8.2-8.4 (8.30)	8.0-8.4 (8.17)	8.1-8.4 (8.27)	8.1-8.4 (8.20)
Organic carbon (%)	0.43-0.59 (0.49)	0.54-0.59 (0.57)	0.50-0.59 (0.54)	0.48-0.59 (0.53)
Available Nitrogen (%)	0.16-0.20 (0.18)	0.10-0.18 (0.14)	0.12-0.18 (0.15)	0.17-0.23 (0.19)
Available Phosphorus	0.28-0.39 (0.35)	0.39-0.52 (0.44)	0.38-0.48 (0.43)	0.29-0.59 (0.41)

Table 6. Cladoceran population (No. l^{-1}) in treatments with and without soil

Days	Treatments*							
	C_0	C_1	DS_0	DS_1	SS_0	SS_1	NS_0	NS_1
5	20	30	520	560	330	350	290	360
10	200	230	840	1070	400	390	630	710
15	410	590	3640	3970	1810	2030	2600	3720
20	310	370	4390	4450	2470	2880	3700	3960
25	240	290	5250	5600	2100	2830	4890	5010
30	170	200	5000	5170	1690	2150	3340	3750
Mean ± SD	225±53	285±76	3273±851	3470±873	1466±365	1772±465	2575±735	2918±779

* ($p<0.05$), level of probability: Error df=8, MSS=1831693 & F=1942.24

Besides attaining higher cladoceran production in the waste treated waters, it was also possible to improve quality of wastewater and presence of soil was found to favour this process of biodegradation. Further, the chemical processes are controlled by the soil in pond through its peculiar buffering action. The present study is in conformity with the observations of Jhingran (1988) and Banerjee & Lal (1990) on the effects of soil on several water quality parameters.

The experiment conducted in this study has clearly exhibited higher cladoceran production in the systems treated with soil and organic wastes. In an aquatic ecosystem (micro or macro) soil acts as a sink for receiving many nutrients from the water phase. This is especially true for the waste waters having high load of nutrients in various forms of nitrogen and phosphorus. Once absorbed in the sediments, these nutrients are released gradually for biological production. Therefore, it is likely that in the absence of soil, high load of nutrients available in water phase may result in the development of algal or periphyton communities which is not much desirable for achieving high production of zooplankton such as cladocerans which have ability to consume bacteria as well as organic matter directly from the media.

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