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Assessment of Fertilised Pond Ecosystem Productivity Using Aerobic Cellulose Decomposing Bacteria as Carbon Signature

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Abstract

The growth response of aerobic cellulose decomposing bacteria (CDB) to qualitatively different fertilisers [cattle manure (CM), poultry droppings (PD), inorganic fertiliser (IF)] were examined in experimental tanks under alluvial and laterite soil conditions as well as in natural ponds with alluvial soil. A mixed application of fertiliser [organic - PD (14 kg); CM (44.5 kg) and inorganic - urea (557g); single super phosphate- 3.14 g] was applied in natural ponds. The maximum CDB population occurred in CM treatment (water: 52 280 x 10^3 mL^{-1}; sediment: 38-278 x 10^4 g^{-1}) followed by mixed application (pond water: 122-212 x10^3 mL^{-1}; sediment: 58-206 x 10^4 g^{-1}), PD (water: 42-195 x 10^3 mL^{-1}; sediment: 21-200 x 10^4 g^{-1}), and IF (water: 3.3-72 x 10^3 mL^{-1} ; sediment: 2.5- 58 x 10^4 g^{-1}). Higher values of C/N (61-116.3) and N/P (1.89-2.28) ratios in the CM treatment suggest that carbon was not limiting in the CM, and the CDB populations therefore can be a good indicator of carbon status in wetlands. Hence, CDB population in pond ecosystem can serve as carbon signature of the system productivity supporting necessary carbon amendments through manuring in the system for enhanced production.

Introduction

Recent years have witnessed a serious threat from the emission of carbon responsible for global warming and climate change for which industries and agriculture are collectively responsible (Philips et al. 2009). In the rice vegetated fields, more than 90% of methane emission was due to plant mediated transport (Hotzapfel-Pschorn et al. 1986; Khalil et al. 2008). Likewise, structure and properties of soil are known to have considerable influence on the carbon emission from organic agricultural fields (Abbas and Fares 2009). The input and mineralisation of organic carbon in anaerobic aquatic sediment is primarily responsible for carbon emission through methane production (Nedwell 1984).

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Promotion of organic farming in recent years is mainly due to the adverse effects of inorganic fertiliser and chemicals, which include changes in soil structure, depletion of soil fertility and loss in soil microflora (Melero et al. 2008). However, the characteristics of aquatic systems are different from terrestrial environment. Comparison of CO_2 evolution rates between terrestrial soils (10-100 $kg{\cdot}CO_2m^{-2}day^{-1}$) and pond water (0.2855 $g{\cdot}CO_2{\cdot}m^{-2}day^{-1}$) indicated that the pond CO_2 evolution is slower than terrestrial soil (Boyd 1995). The interplay between emergent macrophytes and soil microbial processes are quite important for methane emission from natural wetlands (Laoenbroek 2010). Food web structure altered by organic loading in the water bodies has been reported to shift the carbon flux pattern between the lake and atmosphere (Schindler et al. 1997). Enhanced rates of carbon dioxide emission in water bodies have been attributed to the increased rates of organic matter decomposition caused by increased nitrate loading (Stadmark and Leonardson 2005).

Ponds under different soil conditions of India are often fertilised with qualitatively different manures for enhancement of biological production. The interactions between manure, soil quality and microbial community are likely to exert considerable influence on carbon status of the pond that reflects the nature of carbon cycle and carbon sequestration in the system. This is because the ponds located in alluvial soil zones contain greater amount of sediment carbon than those located in laterite soil even though both are treated with the same type of fertilisers. Cattle manure (CM) containing primarily of cellulose, nitrogen, phosphorous, potassium and sulphur (Pillay 1990) is frequently used in India due to its low cost and easy availability (Garg and Bhatnagar 1999).

The decomposition of cellulose, the most abundant component of CM, is very important in the biological cycle of carbon (Gaur et al. 1995; Boulton and Quinn 2000; Sylvia et al. 2005). Indeed, cellulolytic activity or cellulose enzymes of microbial community has been considered to be an important ecological indicator in soil amended with biofertiliser (Zhao and Zhou 2005) or in the production of fuel ethanol from lignocellulosic biomass (Ahamed and Vermette 2009). Substrates with carbon (C), nitrogen (N) and phosphorus (P) are required in appropriate atomic ratio of 106:12:1 for balanced growth of bacteria (Goldman et al. 1987). A CN ratio of 28-29:1 and NP ratio of 3-7:1 in water has been reported to sustain maximum abundance of different nutrient mineralising bacteria (Ghosh and Chattopadhyay 2005). The mixed fertiliser comprising cattle dung (95%), poultry droppings (PD, 2.5%), urea (2%) and single superphosphate (SSP, 0.5%), and with a carbon-nitrogen-phosphorus ratio of 88.6: 7.5: 1, was a suitable cost-effective fertilisation option for aquaculture practices (Jana et al. 2001).

Information on the effect of organic manure decomposition on carbon status of aquatic environment is meager. The purpose of this study was to assess the use of cellulose decomposing bacteria (CDB) as an indicator of the carbon status of the pond as CDB and cellulase enzymes degrading organic matter are likely to be dominant in ponds where CM is utilised. The study may be useful in predicting the role of fertilised ponds in the global scenario of carbon sequestration and climate change.

Materials and Methods

The study was conducted in four natural ponds situated in the alluvial soil zone of the Kalyani township and in 18 experimental tanks (4500 L; 3 m x 1.5 m x 1.2 m) provided with 30 cm layer of either laterite or alluvial soil at the bottom of the tank so as to simulate semi natural conditions of the ponds. By soil structure, laterite soil contained less clay, more silt and sand (sand-60%, silt-25%, clay-15%) compared to alluvial soil (sand-51%, silt-18%, clay- 31%). The tanks were filled with aerated ground water (pH 7.2-7.4, alkalinity 394-402 $mg{\cdot}L^{-1}$, hardness 162-171 $mg{\cdot}L^{-1}$, total dissolved solids 288-296 $mg{\cdot}L^{-1}$; dissolved organic carbon 1.8-2.4 $mg{\cdot}L^{-1}$; nitrate 0.02-0.038 $mg{\cdot}L^{-1}$; conductivity 587-609 $\mu s{\cdot}cm^{-1}$) water loss by evaporation (~1-2 $cm{\cdot}day^{-1}$) was compensated by adding required amount of ground water periodically.

Three tanks with alluvial or laterite soils were allotted to each treatment: CM, PD and inorganic fertilisers (IF). Three natural ponds (pond A- 640 m^3; pond B -1,652 m^3; pond C - 510 m^3) were treated with each of the three fertilisers; the fourth pond (pond D-1,440 m^3) was subjected to input of mixed organic and inorganic fertilisers. The manure dose was selected in accordance with recommended dose for pond fertilisation in India (Jhingran 1995). The dose of PD was based on iso-phosphorus level for CM, PD and IF treatments and iso-nitrogen level for CM and IF treatments. The actual amount of fertilisers applied per tank and per pond every 14 days was as follows: CM - 0.475 $kg{\cdot}tank^{-1}$; 145.76 $kg{\cdot}pond^{-1}$(equivalent to 0.088 $kg{\cdot}m^{-3}$), PD - 0.255 $g{\cdot}tank^{-1}$; 29.6 $kg{\cdot}pond^{-1}$ (equivalent to 0.046 $kg{\cdot}m^{-3}$), IF urea - 5.96 $g{\cdot}tank^{-1}$; 552.65 $g{\cdot}pond^{-1}$ (equivalent to 0.001 $kg{\cdot}m^{-3}$ + SSP- 23.87$g{\cdot}tank^{-1}$; 2.22 $kg{\cdot}pond^{-1}$ (equivalent to 0.0043 $kg{\cdot}m^{-3}$) and mixed (inorganic + organic) - PD (14 kg), CM (44.5 kg) and IF (urea- 557 g ; SSP 3.14 g) in equal proportions.

Samples of water and surface sediment, in triplicate, were collected aseptically in sterile containers from different sites of natural ponds as well as from the experimental tanks of each treatment at a fixed hour of the day (9.00 h) every fortnight during the period of study.

The collected samples were pooled to create a homogeneous sample and then divided into two halves: one-half was used for determination of water quality parameters. All the water quality parameters (temperature, pH, free carbon dioxide, alkalinity, hardness, dissolved oxygen, chemical oxygen demand, dissolved organic carbon, ammonium-nitrogen, nitrite-nitrogen, nitrate-nitrogen, orthophosphate, soluble reactive phosphorus, conductivity, primary productivity and plankton volume) were determined following the standard methods described in APHA (1995). The primary productivity of phytoplankton was determined by light and dark bottle method (Vollenweider 1974) and the second half was used for microbiological examination. Aliquots were prepared with 10^{-3} dilutions for water and 10^{-4} dilutions for sediment samples using sterilised distilled water. The suspension of surface sediment (3 cm) was prepared by mixing 1 g of wet sediment in 99 mL sterilised distilled water (Atlas 2004). Cellulose decomposing bacteria (CDB) capable of utilising cellulose powder as a source of carbon were grown on Petri plates using agar medium with the following composition. Cellulose powder-2.5 g, peptone 0.5 g, potassium hydrogen phosphate 0.2 g, magnesium sulphate 0.2 g, potassium carbonate 0.4 g, calcium chloride 0.2 g, agar 20.0 g and distilled water 1L The medium was sterilised in an autoclave (120 °C) at 15 psi pressure for 15 min. The pH of the medium was maintained at 7.2.

Conventional spread plate technique was used and the culture was expressed as CFUs/mL, under aerobic conditions (Chen and Kueh 1976) at 35 °C for 3 days. This technique was used because of minimum contamination, ease of handling, as well as isolation of colony for characterisation. Arithmetical means of the counts of bacteria from three Petri dishes were used in the study.

Fertliser mineralisation index (FMI) was used for evaluating the nutrient status of the treatment system as a whole and was defined as the net amount of nutrients available in the water phase of the system from allochthonous input fertiliser through various transformation pathways and processes. The FMI was estimated following the method described by Jana et al. (2001):

$$\text{Fertiliser Mineralisation Index (\%)} = \frac{\text{Mean concentration of nutrient of water}}{\text{Mean concentration of nutrients of input fertiliser}} \times 100$$

The sediment samples from the tanks with both the alluvial and laterite soils were collected by hand grabber, air dried, powdered, sieved and then analysed using the method described by Jackson (1967).

All the results obtained from the tanks were statistically evaluated by means of one way analysis of variance (ANOVA) performed separately on different dates of sampling. Three replicates of each treatment were used for analysis of variance.

Results

Bacterial abundance

The density of CDB population ranged from 24.0 to 101.4 x 10^3 mL^{-1} and from 22.0 to 220.0 x 10^4 g^{-1} in water and sediment under different fertiliser treatments, respectively in both simulated ponds (Figs. 1 and 2) and natural fish ponds (Fig. 3). There were no significant differences (ANOVA, $P > 0.05$) between laterite and alluvial soil treated tanks.

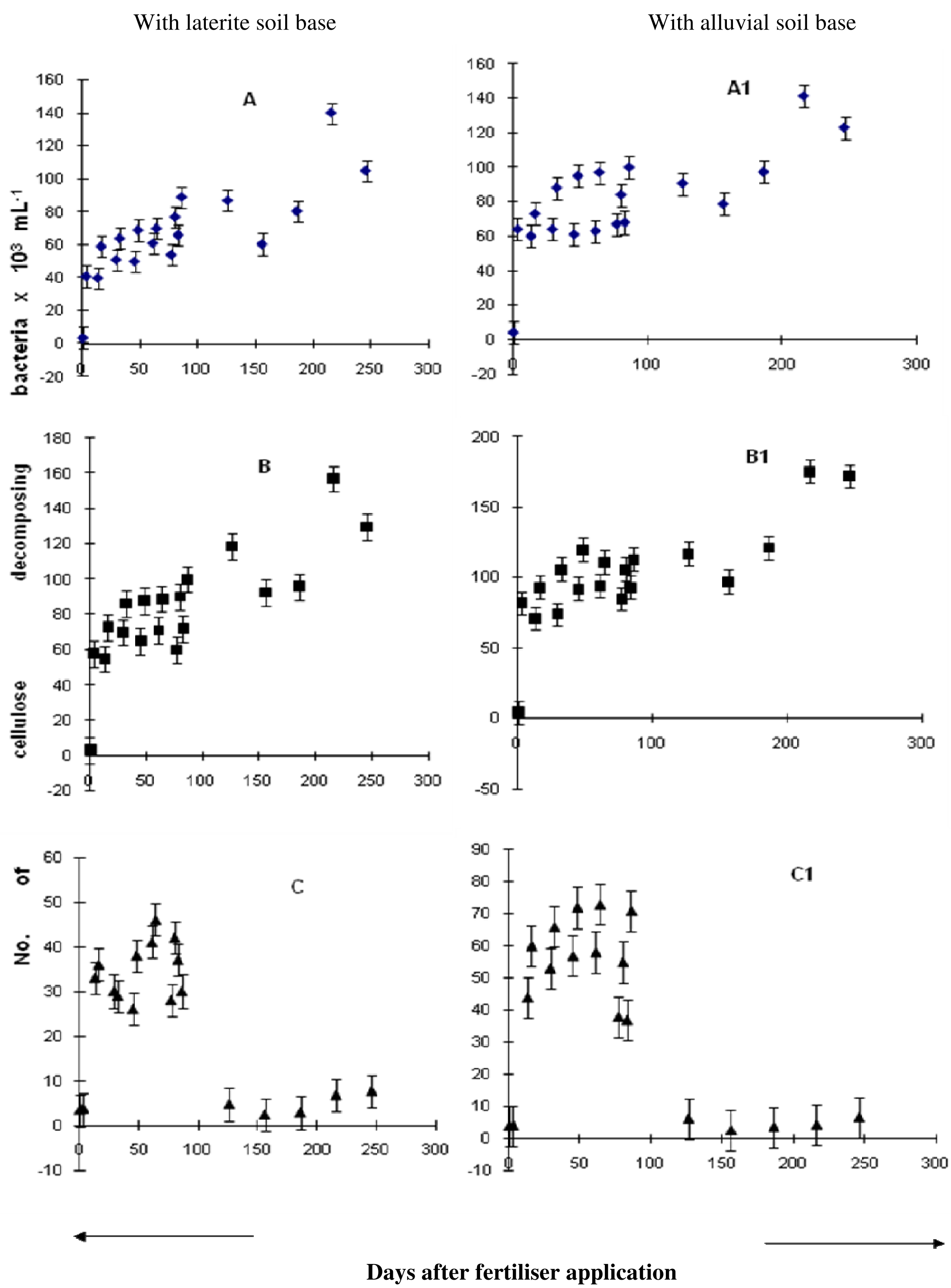

Fig. 1. Responses of cellulose decomposing bacteria in water of tanks treated with different fertilisers, poultry droppings (A, A_1), cattle manure (B, B_1) and inorganic fertiliser (C, C_1) under laterite (A-C) and alluvial (A_1 - C_1) soil conditions. Each value represents the mean (±SE) for four replicates.

First instalment of all the fertilisers in tank and ponds resulted in 2-20 and 15-40 fold increase in bacterial count in water and sediment, respectively. The rate of increase, however, tended to decrease with increase in fertiliser instalments.

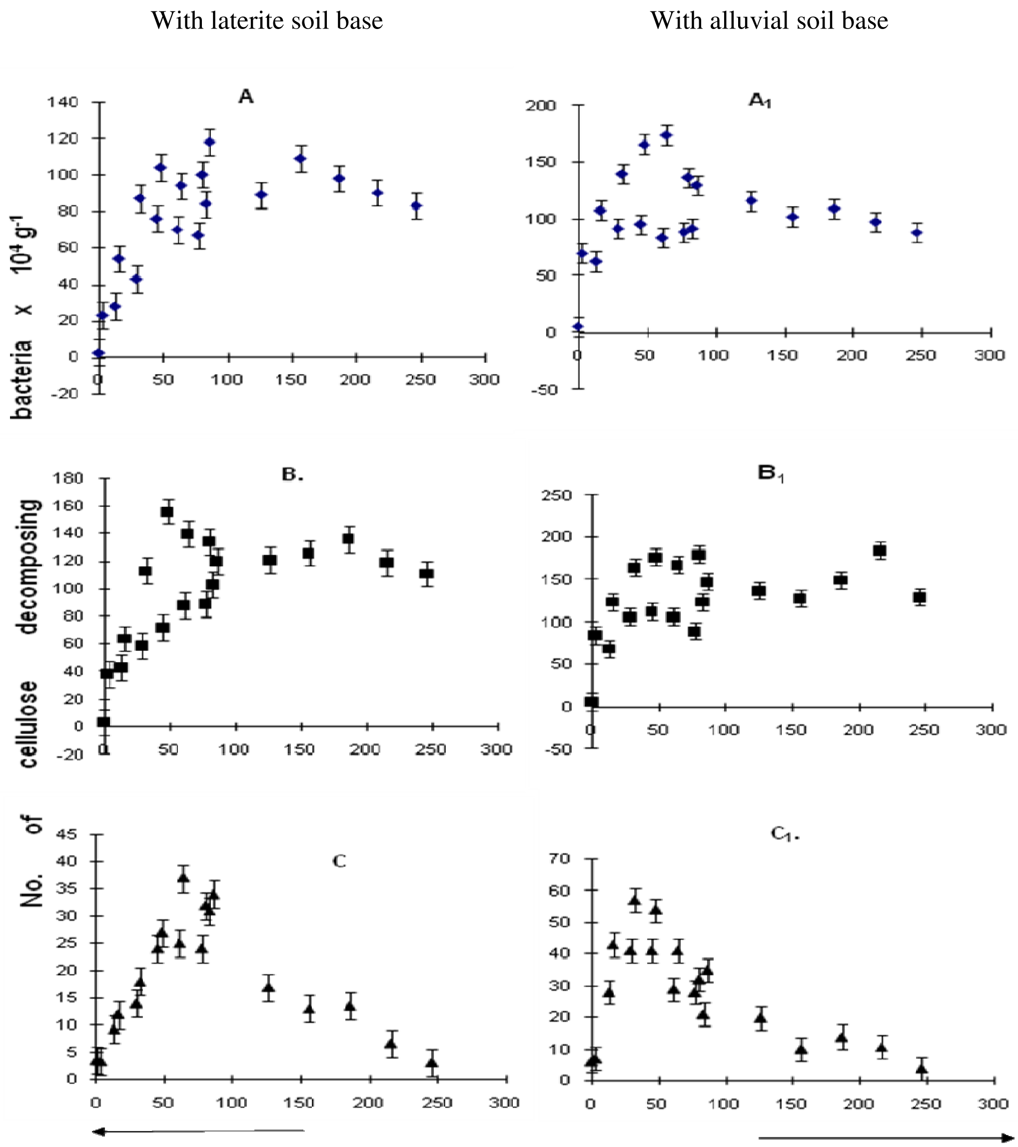

Fig. 2. Responses of cellulose decomposing bacteria in sediment of tanks treated with different fertilisers, poultry droppings (A, A_1), cattle manure (B,B_1) and inorganic fertiliser (C,C_1) under laterite (A-C) and alluvial (A_1 - C_1) soil conditions. Each value represents the mean (±SE) for four replicates.

In tank water, the mean bacterial counts observed in CM were 15-130% and 250-1,300% higher (ANOVA, $P < 0.05$; DMR test) than PD and IF treatment, respectively. In natural ponds too, the count for CM was 50-100%, 3,000-6,000% and 20-200% higher than PD, IF and mixed treatments, respectively (ANOVA, $P < 0.05$).

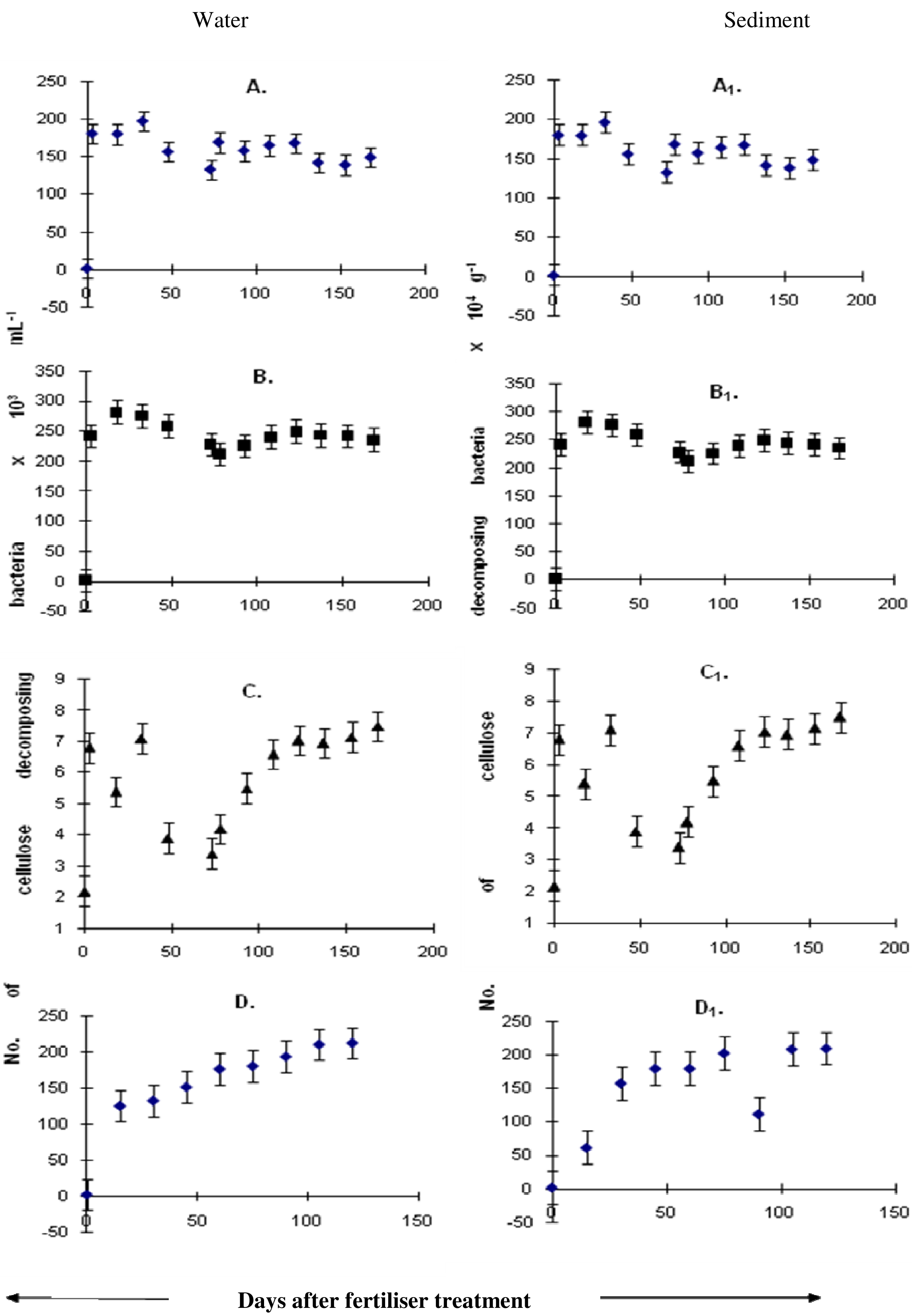

Fig. 3. Responses of cellulose decomposing bacteria in water (A-D) and sediment (A1-D1) of ponds treated with different fertilisers, poultry droppings (A, A1), cattle manure (B,B1), inorganic fertiliser (C,C1) and mixed treatment (D, D1). Each value represents the mean (±SE) for four replicates.

Water Quality

There was a difference in water quality among the three types of fertilisers tested (Table 1 and 2). Water pH was a little lower in natural ponds than in experimental tanks. Evidently, free carbon dioxide was absent from the samples of pond water, whereas, it occurred in the amount ranging from 10-20 $mg·L^{-1}$ in experimental tanks. The values of chemical oxygen demand were highest in the PD (160-170 $mg·L^{-1}$) followed by CM (140 $mg·L^{-1}$) and IF (102-136 $mg·L^{-1}$) treatments in tanks (ANOVA, $P < 0.05$) (Table 1). The concentrations of ammonia-N (0.048-0.097 $mg·L^{-1}$) and nitrite-N (0.018-0.028 $mg·L^{-1}$) of water were highest in the IF treated tanks and ponds. The concentration of nitrate-N, on the other hand, was highest in PD treated (0.08-0.096 $mg·L^{-1}$) tanks and ponds (ANOVA, $P < 0.05$). Likewise, the concentrations of orthophosphate (0.163 $mg·L^{-1}$) and soluble reactive phosphorus (50-113 $\mu g·L^{-1}$) of water were highest in IF treated tanks and ponds with alluvial soil (ANOVA, $P < 0.05$). The values of C/N and N/P ratios of water ranged from 36-116.3 and 1.89 to 2.72 in different treatments of tanks and ponds.

Sediment quality

The soil pH varied between 6 and 7.2 in different treatments with laterite soils and between 7.8 and 8.9 in alluvial soil during the period of study. The amount of organic carbon was highest in CM treated soil (1.12%) followed by poultry droppings (0.98%) and inorganic fertiliser (0.88%) (ANOVA, $P < 0.05$). Poultry droppings treated tanks showed the highest values of total nitrogen (364 $mg·100\ g^{-1}$) and total phosphate (51-52.3 $mg·100\ g^{-1}$) followed by cow dung and inorganic fertiliser (ANOVA, $P < 0.05$).

Fertiliser mineralisation index

The mean values of FMI for carbon were higher than that of phosphorus and nitrogen irrespective of the treatments employed in the tanks (Table 1) and ponds (Table 2). Among the treatments, mean values of mineralisation indices for carbon (41.63), and phosphorus (42.1) were higher than nitrogen (19.73) in the CM treatment than the rest of the treatments employed.

Primary productivity of phytoplankton

The gross primary productivity was maximum in IF treatment followed by CM and PD treatments with laterite and alluvial soil conditions (Table 1). The amount of plankton volume was highest and lowest in PD and IF treatments, respectively (Table 1). The gross primary productivity of phytoplankton was somewhat related with FMI for nitrogen in tanks treated with laterite soil. Under alluvial condition, the gross primary productivity of phytoplankton was inversely related with the values of FMI for carbon.

Table 1. Mean ± SE values of different physico-chemical and biological parameters of water in three treatments under two soil conditions in tanks.

Parameters	Laterite soil			Alluvial soil		
	Poultry Droppings	Cattle Manure	Inorganic Fertiliser	Poultry Droppings	Cattle Manure	Inorganic Fertilier
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Temperature (^oC)	16.6±3.3	22.03±2.4	22.06±2.7	21.9±2.7	22.5±2.7	23.6±2.8
pH	8.5	8.6	8.9	8.1	8.5	9.1
Carbonate alkalinity ($mg \cdot L^{-1}$)	10.9±2.7	19.9±3.2	17.2 ±2.3	13.04 ±2.15	14.2±2.51	19±3.7
Bicarbonate alkalinity ($mg \cdot L^{-1}$)	199±20.9	189.16±20.5	193±19.05	185±12.7	190±11.9	207.5±33.3
Hardness ($mg \cdot L^{-1}$)	202±12.2	185±8.02	185±17.6	217±14.8	209 ±9.1	175±11.02
Dissolved oxygen ($mg \cdot L^{-1}$)	10.8±0.8	11.5±0.9	13.2± 0.47	10.2± 0.8	11.6±1.4	12.45±1.6
Chemical oxygen demand ($mg \cdot L^{-1}$)	170±23.6	140±28.3	102±11.5	160±17.6	140±28.3	136±26.03
Dissolved organic carbon ($mg \cdot L^{-1}$)	9.6±2.1	10.35±2.2	8±2.4	10.25±2.1	11.4±2.5	8.5±1.7
Ammonium nitrogen ($mg \cdot L^{-1}$)	0.04±0.014	0.036±0.009	0.048±.013	0.04±0.012	0.037±0.013	0.05±0.016
Nitrite nitrogen ($mg \cdot L^{-1}$)	0.014±0.004	0.013±0.004	0.018±0.005	0.013±0.005	0.012±0.005	0.019±0.005
Nitrate nitrogen ($mg \cdot L^{-1}$)	0.045±0.01	0.04±0.02	0.07±0.01	0.08±0.028	0.07±0.024	0.051±0.02
Orthophosphate ($mg \cdot L^{-1}$)	0.146±0.06	0.19±0.057	0.153±0.068	0.15±0.07	0.146±0.05	0.163±0.09
Soluble reactive phosphate ($\mu g \cdot L^{-1}$)	50.7±8.6	47.2±7.2	50.7±7.6	50.5±8.2	52.9±6.9	54.8±6.4
Conductivity ($\mu S \cdot cm^{-1}$)	0.38±0.05	0.38±0.038	0.34±0.03	0.43±0.06	0.37±0.06	0.30±0.05
CN ratio	98.0±12.5	116.3±21.6	63.2± 9.5	77.0±12.0	95.7±15.6	70.8±8.36
NP ratio	1.9±0.25	1.9±0.18	2.7±0.68	2.7±0.54	2.3±0.46	2.2±0.32
Gross Primary Productivity ($mgCm^{-3}h^{-1}$)	173.9±6.7	154.3±4.8	128.4±14.2	192.3±75.1	133.3±10.74	136.5±11.3
Plankton volume ($mL \cdot L^{-1}$)	6.5±1.3	5.13±0.96	1.4±0.112	7.05±3.14	5.3± 1.03	1.7± 0.098
Fertiliser Mineralisation Index						
Carbon	0.98	39.6	17.2	1.04	43.6	18.3
Nitrogen	0.146	16.8	44.6	0.198	22.6	39.3
Phosphorus	0.065	44.5	4.71	0.063	39.7	5.2

Table 2. Mean±SE values of different physico-chemical parameters of water in four treatments in natural ponds**.**

.Parameter	Poultry Droppings	Cattle Manure	Inorganic Fertiliser	Mixed Fertiliser
	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE
Temperature (^{o}C)	27.7±3.03	26.9±4.5	26.06±3.5	28.9±4.06
pH	7.6	7.6	7.8	7.9
Free CO_2 (mg L^{-1})	20±2	20±2	15±1.5	10±0.1
Carbonate alkalinity (mg$\cdot L^{-1}$)	0	0	0	0
Bicarbonate alkalinity (mg$\cdot L^{-1}$)	133.3±5.03	145.3 ±4.8	123.2 ±3.8	141± 3.5
Hardness (mg$\cdot L^{-1}$)	89.0±3.72	89.46±2.71	98.76±3.74	103.5± 4.32
Dissolved oxygen (mg$\cdot$ L^{-1})	8.68±1.65	9.02±2.79	8.95±1.41	9.78±1.05
Chemical oxygen demand (mg$\cdot L^{-1}$)	134.9±4.39	118.6±5.75	88.53±3.48	141.4±4.36
Dissolved organic carbon (mg$\cdot L^{-1}$)	10.86±1.25	12.36±1.68	9.3 ±1.54	10.3±1.89
Ammonium nitrogen (mg$\cdot L^{-1}$)	0.123±0.094	0.096±0.082	0.129±0.007	0.097±0.002
Nitrite nitrogen (mg$\cdot L^{-1}$)	0.023±0.006	0.023±0.001	0.032±0.005	0.028 ±0.004
Nitrate nitrogen (mg$\cdot L^{-1}$)	0.096±0.002	0.082 ±0.002	0.1±0.008	0.086±0.0045
Orthophosphate (mg$\cdot L^{-1}$)	0.18±0.01	0.18±0.02	0.28 ±0.009	0.27± 0.005
Soluble reactive phosphate (µg$\cdot L^{-1}$)	0.091±0.005	0.093±0.018	0.113±0.009	0.084±0.002
Conductivity (µS$\cdot cm^{-1}$)	0.36±0.05	0.31±0.06	0.3±0.035	0.31±0.025
CN ratio	44.8±6.7	61.5±8.2	36.0±4.6	49.0±5.2
NP ratio	2.6±0.68	2.2±0.52	2.3±0.53	2.5±0.48
Fertiliser Mineralisation Index				
Carbon	1.35	5.4	4.9	10.02
Nitrogen	0.44	0.045	0.01	0.63
Phosphorus	0.14	5.3	0.013	0.054

Discussion

The biological productivity in pond system is strongly regulated by the nutrient status contributed by the input of inorganic nutrients mediated through allochthonous and autochthonous sources. In India, cattle manure is a frequently used manure in commercial ponds (Kamanga and Kunda 1998) and play an important role in the enhancement of fish production by the way of providing major nutrients for the production of phytoplankton to zooplankton and fish through food chain phenomenon.

Quantitative dominance of CDB population in the cattle manure treated pond or tanks compared to the remaining treatments (PD, IF and mixed fertiliser) was perhaps due to the presence of increased amount of cellulolytic materials (cellulose, hemicelluloses and lignin) which, in turn, were responsible for quantitative selection of CDB population in the cattle manure treated tanks or ponds. The higher ratio of organic matter to CDB population in the cattle manure treatment compared to poultry droppings implied a strong affinity of CDB population for digestion of cellulolytic materials contained in the cattle manure. It is known that the amount of cellulose (17-25% dry matter) and hemicelluloses (21-22% dry matter) was much higher than lignin (8-13% dry matter).

As cellulose degradation occurs under both aerobic and anaerobic conditions involving multiple enzyme systems (Atlas and Bartha 2000), the same will also hold true for the present experimental set ups. Various fungi, aerobic and facultative anaerobic bacterial populations and the anaerobic cellulose fermenter such as *Clostridium* are responsible for cellulolytic activities. This resulted in common production of carbon dioxide, water and cell biomass under aerobic and anaerobic condition, apart from the production of low molecular weight fatty acids under anaerobic condition. Since fermentation under anaerobic condition yields less energy per unit of substrate consumed than respiration, cellulose-fermenting bacteria degrade large quantities of cellulose in order to generate cell biomass (Atlas and Bartha 2000). Likewise, hemicelluloses which are polysaccharides composed of various arrangements of pentoses are degraded by fungi and bacterial populations involving the endoenzymes system. In other words, the biodegradation rate of lignin is much lower than for either cellulose or hemicelluloses compounds (Atlas and Bartha 2000).

As the cellulolytic materials of the cattle manure upon degradation resulted in higher concentration of dissolved organic carbon in water and organic carbon in sediment, the direct relationship between the CDB populations and the concentrations of dissolved organic carbon of water (Fig 4, $r = 0.852$; $P < 0.001$) was most anticipated. The higher values of FMI coupled with greater abundance of CDB population in the cattle manure treatment compared to poultry droppings revealed that the composite CDB population was responsible for degradation of different components of cellulolytic materials of the cattle manure involving multiple enzymatic systems of CDB populations. This shows that enumerated CDB population could be profitably used to indicate the carbon status of the pond system.

The results of nutrient variability among the treatments showed that the carbon mineralisation was more active and dynamic in cattle manure with increased level of organic carbon in the system, whereas, turnover of nitrogen and phosphorus was more in the PD and IF treatments, respectively (Table 1 and 2).

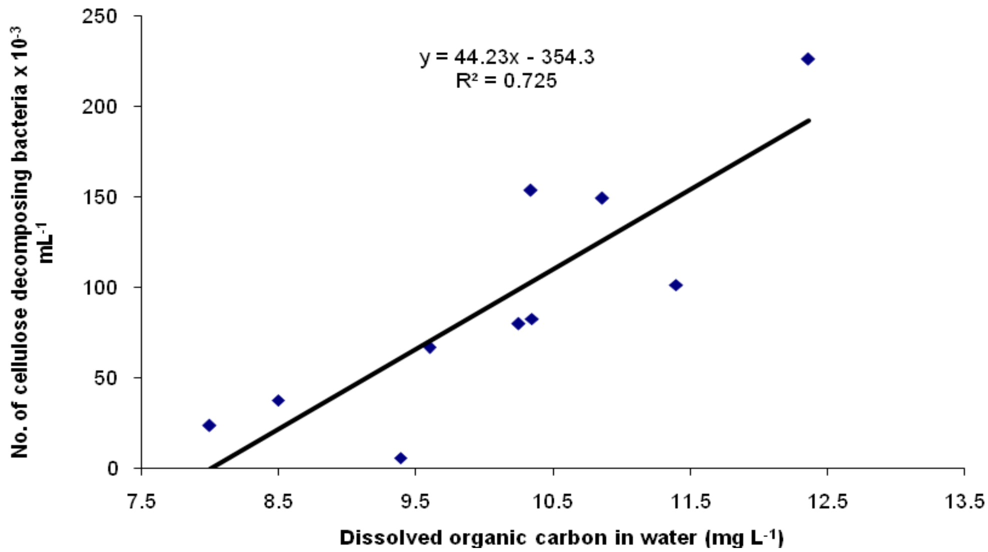

Fig. 4. Relationship between cellulose decomposing bacterial population and concentration of dissolved organic carbon in water.

The results of the study further showed that gross primary productivity and plankton volume in the culture units were the direct and inverse functions of phosphate concentrations and N/ P ratio, respectively. The carbon status of the pond relative to phosphorus and nitrogen, on the other hand, plays an important role in determining the primary productivity of phytoplankton which serves as the base of the grazing food chain of fishes. It shows that the cattle manure system was not carbon limited because CP and CN ratios were maximum in this treatment. It is reasonable to assume that carbon relative to nitrogen or phosphorus was the main driving force in determining the CDB populations and decomposition of cattle manure in the pond system. Researches have shown that bacterial growth efficiency decreases about 100 fold with increasing CN and CP ratios in their substrate (Goldman et al. 1987). A significantly higher (2.5-6 times) microbial decomposition rate has been observed in manure ponds than in chemically fertilised ponds (Zhu et al. 1990). Therefore, it appears that the carbon status of the pond could be regulated by manipulating the dose of cattle manure that determines the abundance of CDB populations in the system in question.

Conclusion

It is reasonable to conclude that CDB population in pond ecosystem can be used as carbon signature of the system productivity both in ecological and economic terms supporting necessary carbon amendments through pond fertilisation in the system for enhanced production. Aerobic carbon decomposing bacteria may also be used as an indicator of the carbon status and algal biomass of the ecosystem under different soil conditions, and therefore play an important role in the global scenario of carbon sequestration and climate change.

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