Research Article

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Insights in Aquaculture and Biotechnology

2017
Vol.1 No.1:1

Influence of Commonly used Manures on the Growth and Nutrient Composition of Periphyton

Gangadhar B[1], Umalatha H[1], Hegde G[1], Vasundhara R[2] and Sridhar N[1]

[1]ICAR, Central Institute of Freshwater Aquaculture, Regional Research Centre, Hesaraghatta Lake, Bangalore, India

[2]ICAR, National Bureau of Soil Survey and Land Utilisation Pattern, Regional Station, Bangalore, India

Corresponding author: Gangadhar B, ICAR, Central Institute of Freshwater Aquaculture, Regional Research Centre, Hesaraghatta Lake, Bangalore, India, Tel: 9180 28479891; Fax: 9180 28479891; Email: gbarlaya@yahoo.co.in

Received date: December 10, 2016; **Accepted date:** January 31, 2017; **Published date:** February 07, 2017

Citation: Gangadhar B, Umalatha H, Hegde G, et al. Influence of Commonly used Manures on the Growth and Nutrient Composition of Periphyton. Insights Aquac Cult Biotechnol. 2017, 1:1.

Abstract

A 90 day experiment was conducted in out-door, soil-based (10 cm), cement tanks to evaluate the effect of three manures viz. cattle dung, poultry manure and press mud provided at iso-nitrogenous levels, on the growth and nutrient composition of periphyton grown on sugarcane bagasse. Water quality analysis revealed that tanks applied with cattle dung recorded lower ($P>0.05$) pH and those with poultry manure showed higher ($P>0.05$) phosphate content. Total pigment content and biomass of periphyton (dry matter) and plankton (dry weight) showed higher values in poultry manure treatment. Press mud treatment recorded lower plankton dry matter. Crude protein and fat contents were higher ($P<0.05$) in periphyton from poultry manure treatment. Other proximate composition parameters showed no difference ($P>0.05$) among periphyton from different treatments. The proximate composition of plankton also showed higher crude protein, fibre and ash values in poultry manure. The study revealed that poultry manure is superior to cattle dung and press mud, considering the total pigment content, biomass and crude protein content of periphyton and plankton biomass.

Keywords

Periphyton; Plankton; Cattle dung; Poultry manure; Press mud

Introduction

Pond fertilization is a common practice in aquaculture aimed at increasing the production of natural food for farmed fishes. Inorganic fertilizers are expensive and their use by smallholder farmers may be limited [1]. Animal wastes are widely used in many countries to sustain pond productivity at a low cost [2, 3]. Organic fertilizers decompose and release nitrogen, phosphorous and potassium which are used by phytoplankton for growth and reproduction. In addition, they provide attachment sites for bacteria and other microscopic organisms. Plankton perform other important functions in pond aquaculture - a net producer of dissolved oxygen, which is indispensable for fish growth [4] and the most important sink of ammonia-nitrogen, which is excreted by fish [5, 6]. Jhingran [7] observed that natural food also supplies certain digestive enzymes that improve the utilization of artificial diets.

The FAO/AADCP Regional Expert Consultation has emphasized the need for a greater understanding of the role of natural food organisms in semi-intensive farming based on systems that optimize pond fertilization [8]. Judicious organic fertilization of fish ponds can eliminate the need for supplementary feeding [9]. The use of manures such as poultry manure, dung from cow, sheep, goat or pig is well established [10-16]. In India, cattle manure is frequently used in commercial ponds due to its low cost and easy availability [17, 18]; it plays an important role in the enhancement of fish production by providing major nutrients for the augmentation of phytoplankton- zooplankton food chain. Among the organic manures, poultry manure is considered to be the best since it contains more N and P, which play a vital role in plankton production [19]. Poultry manure is now widely used in commercial freshwater aquaculture. Press mud, a sugar factory waste, is a good source of organic matter. It is rich in potash and phosphorus and is used as manure in agriculture [20]. With a conservative yield of 2% and a total production of 1700 million t of sugarcane in 2009 [21], the world output of press mud can be estimated to be about 30 million t.

Facilitating the growth of periphyton by installing substrates in ponds adds a new dimension to natural food production. Periphyton is readily consumed by browsers such as rohu and fimbriatus and is also helpful in improving water quality by producing oxygen, trapping suspended solids and taking up ammonia and nitrate. Studies have demonstrated comparative growth of carps in periphyton-based systems and feed-driven systems [22-24].

Although some investigations have been performed on the effect of fertilizers on plankton production [25, 26], comparative studies on the effect of poultry manure, cattle dung and press mud on the growth of periphyton are lacking. Therefore, the present study was undertaken with the aim of determining the effect of these manures on the quantity and quality of periphyton grown on sugarcane bagasse and also plankton biomass in the tanks.

Materials and Methods

Tank preparation

This experiment was conducted for 90 days in nine out-door, soil-based (10 cm), cement tanks of 4 × 4 × 1 m. Locally available manures, cattle dung (CD), poultry manure (PO) and pressmud (PM) were used for evaluation. While cattle dung was applied as per recommendations for periphyton-based aquaculture [27], the quantity of poultry manure and press mud was calculated based on their nitrogen content, estimated by Kjeldahl method. All the three manures were applied at iso-nitrogenous levels. The fortnightly doses of CD, PO and PM worked out to 7.2, 1.35 and 2.15 kg 16 m-2 tanks. Triplicate tanks were used for each manure treatment. Sugarcane bagasse was suspended vertically using nylon rope at 2 tha-1 for periphyton growth [28]. The tanks were filled with water from a bore well and the level was maintained at 90 + 2 cm. Evaporation loss was compensated fortnightly.

Water quality measurements

Dissolved oxygen, pH, temperature, total alkalinity, transparency, nitrate, total ammonia and phosphate content of tank water were estimated at 09.00 hronce in ten days, following standard procedures [29].

Biochemical analyses

Representative samples of cattle dung, poultry manure and press mud was analysed using standard methods. Analysis of dry matter was done by drying pre-weighed samples in an oven at 100°C for about 16 h to reach a constant weight. Nitrogen was analysed using Kjeldahl method, and phosphorus and potassium using spectrophotometry and flame photometry. From each tank, quantitative periphyton samples were collected in triplicate at 15 day intervals by carefully scraping the hard surface area (10 × 10 cm) from three bundles of bagasse using a blade. The samples thus collected were used for the analysis of chlorophyll-a, biomass (dry weight) and proximate composition parameters viz. moisture, crude protein, crude fat, crude fibre, ash and nitrogen-free extract [30]. Crude protein content of dry matter was calculated using the nitrogen to protein conversion factor of 5.8 suggested by Gnaiger and Bitterlich [31], who found this to be a more appropriate value for bacteria, algae and aquatic invertebrates than the 6.25 that is usually applied. The gross energy content was calculated using values of 22.6 kJg-1 for protein, 38.9 kJg-1 for lipid and 17.2 kJg-1 for carbohydrate as nitrogen-free extract (NFE) [32]. Plankton biomass of the tank water was also analyzed at 15 day intervals by filtering 100 litres of water through bolting silk cloth of 15 µm mesh size. The samples were subjected to proximate composition analysis as that of periphyton.

Statistical analysis

Data on periphyton and plankton was compared employing one-way analysis of variance. Pair-wise comparison of treatment means was done by Duncan's multiple range test (P=0.05) [33], when a parameter was significant.

Results

The nutrient composition of manures used in the study is given in Table 1. While poultry manure had higher NPK content, cattle dung and press mud had almost similar values. The results of water quality analyses are depicted in **Figure 1**. All the parameters monitored showed significant variation during the experimental period. Water pH increased with the experimental duration. Tanks applied with cattle dung recorded lower (P>0.05) pH and those receiving poultry manure showed higher (P>0.05) phosphate content. Other parameters did not show any significant variation among the different treatments.

Table 1 Major nutrient composition (%, Mean ± SD on dry weight basis) of the organic manures applied in experimental ponds.

	Cattle dung	Poultry manure	Press-mud
Dry matter	20.3	89.48	52.19
Nitrogen	1.43 ± 0.05	2.04 ± 0.05	1.49 ± 0.05
Phosphorus (P_2O_5)	0.70 ± 0.03	1.30 ± 0.08	0.83 ± 0.04
Potassium	0.58 ± 0.01	0.65 ± 0.02	0.54 ± 0.03

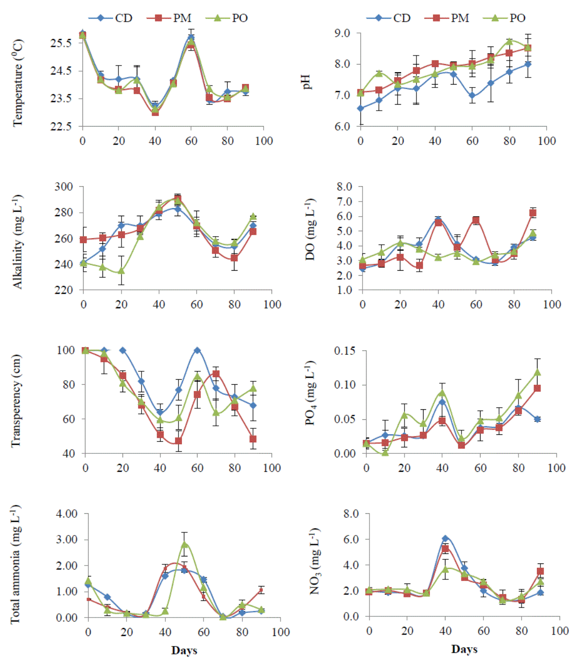

Figure 1 Water quality parameters in tanks receiving different manures.

Total pigment content and biomass of periphyton (dry matter) and plankton (dry matter) showed higher values in poultry manure treatment **(Figure 2)**. Pressmud treatment recorded lower plankton dry matter. The increase in periphytic biomass stabilized at 75 days of experiment.

Data on proximate composition analysis of periphyton and plankton is given in **Tables 2 and 3**, respectively. Crude protein content was higher (P<0.05) in periphyton from poultry manure treatment. Other parameters showed no difference (P>0.05) among periphyton from different treatments. The proximate composition of plankton also showed higher crude protein, crude fibre and ash values in poultry manure compared to other manures.

Table 2 Proximate composition (%, Mean ± SD on dry weight basis) of periphyton, values with the same superscript in each column are not significantly different (P>0.05)

Manure	DM	Crude protein	Crude fat	Ash	Crude fibre	NFE	Gross Energy (kJ/g)
Cattle dung	18.25 ± 2.35a	24.48 ± 0.66a	2.04 ± 0.06 a	32.21 ± 0.54 a	8.57 ± 0.39 a	32.70 ± 0.73 b	11.95
Poultry manure	18.07 ± 1.16a	27.02 ± 0.22b	2.36 ± 0.04 b	32.93 ± 0.15 a	7.58 ± 0.15 a	30.11 ± 0.23 a	12.20
Press mud	17.86 ± 2.31a	23.90 ± 0.45a	1.78 ± 0.09 a	34.20 ± 0.58a	7.64 ± 0.38 a	32.48 ± 0.16b	11.68

Table 3 Proximate composition (%, Mean ± SD on dry weight basis) of plankton, values with the same superscript in each column are not significantly different (P>0.05)

Manure	DM	Crude protein	Crude fat	Ash	Crude fibre	NFE	Gross Energy (kJ/g)
Cattle dung	12.25 ± 2.05a	29.73 ± 0.57a	4.28 ± 0.21a	23.69 ± 2.12ab	3.87 ± 0.01a	38.43 ± 2.13a	14.99
Poultry manure	11.25 ± 1.06a	32.41 ± 0.85b	5.32 ± 0.16a	24.48 ± 1.15b	7.18 ± 0.04c	30.61 ± 1.12a	14.66
Press mud	10.96 ± 1.02a	28.11 ± 1.43a	4.80 ± 0.12a	21.29 ± 1.56a	5.53 ± 0.21b	40.27 ± 1.49a	15.15

Discussion

Fluctuations in dissolved oxygen were less under poultry manure treatment with consistent lower values, compared to other treatments. This may be attributed to the higher demand for oxygen during morning hours by the higher load of planktonic and periphytic organisms in the treatment **(Figure 2)**. A decrease in dissolved oxygen following organic manuring has been demonstrated in earlier studies [34-36].

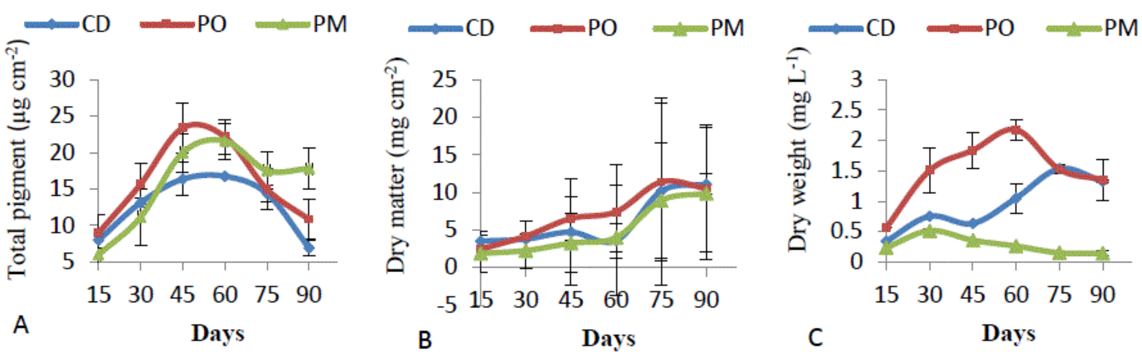

Figure 2 Total pigment content (A), biomass (dry matter) of periphyton (B) and biomass (dry matter) of plankton (C) (Mean ± SD) recorded in different treatments.

Excepting on day 70, the transparency of water was lower under PM treatment, compared to the other treatments, though the treatment recorded lower plankton dry matter. Boatong et al. [37] recorded no significant variation in transparency among the ponds fertilized with cattle dung and poultry manure though there was higher phyto and zooplankton production with the latter. Lower pH in ponds fertilized with cattle dung compared to those with poultry manure as observed in the present study was also reported by Boatong et al. [37]. Cattle dung is known to reduce pH when applied to fish culture ponds [38].

The mean periphyton biomass recorded in the present study (7.1, 6.1 and 5.0 mg cm-2 in poultry, cattle dung and press mud, respectively) was higher than that in grazed systems [39-41]. This may be attributed to the absence of periphyton grazers. The decomposition of organic manure in fish pond is carried out by bacteria, fungi and actinomycetes [42, 43]. Periphytic biota, including these organisms would have contributed to higher nutrient release for periphytic growth.

Manures have been found to influence the natural productivity differently in terms of abundance and prevalence of phyto and zooplankton as well as the benthic organisms in ponds. According to Liebig's Law of the Minimum [44], plant growth is limited by the nutrient present in shortest supply relative to its need by phytoplankton. Phytoplankton and other aquatic plants are limited most commonly by inadequate nitrogen and phosphorus supply. Since all the treatment tanks received manures at iso-nitrogenous level, the variation in periphytic and planktonic quantity recorded in the present study is attributable to phosphorus content. Phosphorus, though required in small quantities for aquatic biota, is the single most important element in water, because of its necessity for plankton growth. Poultry manure is a rich source of phosphorus compared to other manures **(Table 1)**. The availability of all the inorganic nutrients from poultry manure was reported to be considerably higher than that from cattle manure [45]. Studies comparing different organic manures, including poultry manure and cattle dung, for plankton production have revealed that poultry manure is the best among them [10, 19, 46, 47]. Lahiri et al. [48] also reported higher planktonic density in ponds applied with poultry manure compared to cattle dung, indicating that gross primary productivity and plankton volume in the culture units were the direct functions of phosphate concentrations.

Keshavanath et al. [49] recorded higher plankton biomass in press mud applied ponds compared to cow dung treated ponds. However, in the present study, the plankton biomass was the lowest under press mud treatment. In spite of reports on beneficial effects of press mud, disadvantages of press mud are also presumed [50]. If press mud is directly applied to soil as manure, the wax present might deteriorate the physical properties such as permeability, aeration, soil structure, composition, etc. and with the passage of time the deterioration might worsen. Solaimalai found that press mud application to rice crop did not influence the production. In soybean cultivation, press mud application reduced seed yield compared to enriched farm yard manure [51]. However, seed yield and protein content increased when press mud was applied along with recommended fertilisers [52]. These results indicate that the beneficial effect of press mud alone as manure is not universal.

The mean total pigment content in periphyton was 16.0 from PO treatment compared to 15.7 from PM and 12.6 µg cm-2 from CD. Kong'ombe et al. [53] recorded higher chlorophyll content of plankton under PO manuring compared to CD, indicating that there was a higher level of phytoplankton production in the former. The pigment content of periphyton showed an increasing trend up to 45-60 days and then decreased in all the treatments. This may be attributed to decreased productivity of older periphyton [54]. Continuous grazing results in higher periphyton productivity [55]. Since fish were absent in this experiment, only minimal grazing would occur by zooplankton, molluscs and other invertebrates.

The crude protein (CP) and fat contents in periphyton were lower (CP 23.90 to 27.02%; fat 1.78 to 2.36%) than that of the plankton (CP 28.11 to 32.41%; fat 4.28 to 5.32%). Azim [27] also recorded slightly higher nutritional value for plankton (27-50% protein, 2-5% lipid, 8-24% ash and 18-23 kJ g-1 energy) than periphyton. Hepher [56] reported 18-31% protein, 4-10% lipid and 27-48% ash (on dry matter basis) for planktonic algae in ponds depending on the taxonomic group. Proximate composition of periphyton from different substrates varied from 9-32% protein, 2–9% lipid, 25–28% NFE and 16–42% ash [57]. Our earlier findings with periphyton from sugarcane bagasse grown with poultry manure revealed the following proximate composition: crude protein 26.06%, lipid 3.08%, NFE 38.02% and ash 17.45% [58]. Excepting for ash and NFE, the other parameters were comparable to the values obtained in the present study. The ash content of the periphyton did not vary between treatments, but varied between periphyton and plankton, with lower values in the latter. The ash content of periphyton ranged between 36.21 to 38.20% as against 21.29 to 24.48% in plankton. Azim et al. [57] recorded 41% ash from hizol substrate. Ash content was higher in the absence of grazing by fish [55, 59]. As observed in the present study, Kong'ombe et al. [53] also reported higher ash, protein and energy contents for zooplankton under poultry treatment, compared to cattle dung. The higher crude fibre content in periphyton samples compared to that in plankton is an indication of higher biomass of algal species in periphytic biomass, compared to free plankton as reported earlier [24].

Conclusion

Among the three manures compared, poultry manure performed better. Boyd and Hossain [60, 61] reported that despite iso-phosphorus content, the nutrient status of poultry manure is superior to cattle dung or inorganic fertilizers when these are used alone. Not only the amount of phosphorus is high in poultry manure compared to cattle dung, but also the availability in inorganic form which is more easily available than the organic form (90% compared to 75% in cattle dung). Further, poultry manure contains easily decomposable components most of which are in the form of urea and uric acid [62]. Poultry manure had the highest levels of total N, P and narrowest ratios of C/N and C/P, suggesting superior mineralization of organic forms of N and P from it, compared to dairy cow manure [62]. The nutrient composition of cattle dung and press mud were similar. Reflection of this could be seen in their more or less similar performance.

The results of the present study indicate that poultry manure is superior to cattle dung and press mud when used in a periphyton based aquaculture system.

Acknowledgement

The authors are grateful the Department of Biotechnology, New Delhi for funding support through project No. BT/PR5388/AAQ/3/594/2012.

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