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Comparative studies on the aquatic productivity through organic and inorganic fertilizers

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Abstract
In the present experiment, effects of organic (chicken droppings and cow dung) and inorganic fertilizers (urea and single super phosphate) on aquatic productivity was studied with a view to standardize minimum effective dosage for getting higher primary productivity without affecting physic-chemical parameters. The present experiment was conducted in 27 plastic tubs (75 Ltrs) for 60 days trial. The results showed significance different (P<0.05) in physic-chemical parameters and primary productivity among different treatments. Temperature (26-32°C) and alkalinity (183 to 264 mg/L) remained within range, but dissolved oxygen and pH showed declining trend except pH in T_3 (8.00±0.65). Highest primary productivity was observed in tanks fertilized with inorganic fertilizers (489.37 gm) and was remained stable throughout the experiment (525.3±2.53 mgC/m^3). Higher amount of organic manuring depleted water quality while lower amount lead to insufficient primary productivity. Hence, the present protocol can be utilized by small farmers doing extensive or semi-intensive farming to reduce input cost.

Keywords: Organic manuring, Inorganic fertilization, physico-chemical parameters, primary productivity

Introduction
Aquaculture, though considered having a long history, but it was transferred to an economic earning industry only during the second half of the 20th century. Within a period of 25 years, it had started as an important food production sector, having an annual average growth rate of 4.5% in India [1]. Asia has a long history of using organic and inorganic fertilizers for pond based aquaculture. The dynamics of fertilizer use and their efficacy in aquaculture is fairly well understood [2]. Indian aqua-farmers use fertilizers for carp culture to enhance fish yield mainly through mineralization and microbial degradation [3] which finally lead to increased natural food production [4]. Use of commercial feed is expensive, so natural food is the ultimate source of nutrition for the fishes. 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 systems to optimize pond fertilization [5].

Organic manures and inorganic fertilizers are being used from decades to increase the planktonic biomass and to improve water quality for getting economic returns [6]. The ultimate goal of fertilization is to develop appropriate environmental conditions intended for the production of live food organisms. Inorganic fertilizers increase the level of primary productivity, algal biomass, dissolved oxygen, pH and total phosphates when compared with organic manures [7]. Pond fertilization management protocols include both organic manure and inorganic chemical fertilizers to enhance biological productivity [8]. Assessment of fertilizer value of different organic manures has been a subject of research in aquaculture from decades [9].

Pond fertilization is one of the important factors in aquaculture, but it is addressed very rarely through scientific assessments. The relation of nutrients, planktonic and fish growth is a multifaceted subject but practitioners fail to formulate solutions without detailed practical deliberation. A review carried out by Das and Jana [10] indicated that one of the most significant issues for pond fertilization was to determine optimum amount of fertilizer to be added in the system. The primary objective of pond fertilization is to maintain the optimal nutrient concentration and physico-chemical parameters of water for sustained biological production. It is not possible to increase the production of cultivatable fish by giving them the greater quantities of natural food directly [11]. Jasmine *et al.* [12] reported that application of cow dung at the rate of 0.10 gm nitrogen per 100 gm of wet fish weight daily, significantly increased *Catla catla, Labeo rohita and Cirhinus mrigala* production in one year pond fertilization trial. Similarly, Ponce-Palofax *et al*. [13] studied effect of fertilization in the carp polyculture and focused to address issues about the effect of chemical and organic fertilization on water quality and growth of carp.

Abdel-Tawwab and Wafeek [14] reported that chemical fertilizer showed better phytoplankton production, primary productivity and aquaculture production compared with sheep and pig liquid manures. Again they reported highest yield (10.06 ± 0.67 kg/ha/day) with chemical fertilization when compared with pig (8.27 ± 1.24 kg/ha/day) and sheep liquid manures (6.33 ± 1.95 kg/ha/day). In contrast, concentrations of phytoplankton were significantly (p<0.05) higher in ponds fertilized with sheep 945.940 cells/ml) and pig liquid manures (1,157,706 cells/ml) than in chemical fertilized ponds (744.560 cells/ml). Some walleye hatcheries were able to increase fish survival and yields using a well-monitored inorganic fertilization program [15], or a combination of both organic and inorganic fertilization [16]. However, some researchers have suggested that organic fertilizer is necessary to produce algae with required carbon [17] while inorganic fertilizers help to maintain other essential nutrients [18]. Azim *et al*. [6] observed optimum dosage of cow dung, urea and TSP at 4500,150 and 150 kg/ha, respectively with 2-3 week interval between two fertilization dates while Jatindra *et al.* [19] reported that water quality parameters varies highly in different doses of fertilizers over time.

Hence, the present experiment was conducted to standardize minimum effective dosage of fertilizers with the aim to maximize primary production without affecting physico-chemical parameters of the system.

Materials and methods

Experiment site and Tanks arrangement

The experiments were conducted in 27 plastic tanks each one of 75 L capacity at the CIFE, New campus hatchery, off Yari Road, Versova, Mumbai. Plastic tanks with a 10 cm layer of loamy soil at the bottom of each tank as a prerequisite before manure application for establishing environmental conditions to have optimum plankton production [20].

Manure preparation

The organic manures were collected from local animal husbandry farms and allowed to decompose for 10 days before application. Inorganic fertilizers were procured from local market.

Experimental design

The present study followed Completely Randomized Design (CRD) using three treatments at three different dosages of inorganic (urea and single super phosphate) and organic fertilizers (cow dung and poultry manure) for 60 days. Treatments used in the experiment along with their applications have been summarized in Table 1.

Table 1: Treatments showing level of dosages

Treatment	T_1 (Urea+ ssp) (mg)	T_2 (Chicken drop) (g)	T_3 (Cow dung) (g)
Level 1	163.13	45	112.5
Level 2	326.25	60	150
Level 3	489.37	75	187.5

Water quality parameters

For water quality parameters, the water samples were collected from each tank and temperature and pH were measured at the site itself. For other parameters like dissolved oxygen, total alkalinity, free carbon dioxide and primary productivity, water samples were fixed at the site and analyzed in water testing laboratory. Analysis was done following standard methods of APHA [21].

Statistical analysis

Initially, obtained data was kept for normality testing using Shapiro-Wilk's W-statistics (PAST, version 16.0). The experimental data were statistically analysed using SPSS software (version 16.0 for windows). One-way ANOVA was used to compare significant differences between treatments. Significant differences between two means were tested using Duncan's multiple range tests ($p < 0.05$). The results are presented as mean ± standard error (SE).

Results

The results of 60 days experimental trial for assessment of water quality parameters and primary productivity of the system with three treatments at three different dosages are presented in Table 2 and 3, respectively.

Physico-chemical parameters

Physico-chemical parameters of the present experiment showed significant variation within and between treatments (P < 0.05). In case of temperature, no significant difference was observed between different treatments on 15th day of sampling. Temperature showed a trend with slight difference among the treatments and the highest value was recorded in T_3 (32.43 ± 0.29) while the lowest was observed in T_2 (31.00 ± 0.57) on 30th day. The dissolved oxygen varied significantly with highest value recorded on 15th day in T_1 (5.03 ± 0.09) and lowest in T_3 (4.80 ± 0.05). On 30th, 45th and 60th day, similar trend was observed in different treatments. Highest pH values was observed in T_1 (7.36 ± 0.33) and lowest in T_2 (7.10 ± 0.05) on 15th day of sampling. Again on 30th and 45th day of sampling, T_1 recorded the highest value but on 60th day of sampling the highest pH was noticed in T_3 (8.00 ± 0.65) while the lowest was observed in T_2 (6.45 ± 0.19) (Fig. 1).

Alkalinity varied significantly on 15th day of sampling with highest content noticed in T_3 (245 ± 2.88). Similar trend was observed between different treatments on 30th and 45th day of sampling. But on 60th day of sampling, highest content was observed in T_1 (239 ± 2.88) and T_3 (251 ± 7.00) with no significant difference and lowest value recorded in T_2 (183 ± 7.31).

Table 2: Physico-chemical parameters observed during treatments

Treatment	15 day	30 day	45 day	60 day
Temperature (°C)				
T_1	31.63±0.31^{a}	31.90±0.10^{ab}	32.10±0.48^{a}	33.03±0.31^{a}
T_2	31.70±0.35^{a}	31.00±0.57^{b}	32.00±0.57^{a}	32.90±0.40^{a}
T_3	31.40±0.30^{a}	32.43±0.29^{a}	32.00±0.57^{a}	32.70±0.40^{a}
Dissolved oxygen (mg/L)				
T_1	5.03±0.09^{a}	4.80±0.11^{a}	4.59±0.20^{a}	3.93±0.25^{a}
T_2	4.83±0.03^{ab}	4.33±0.17^{ab}	3.90±0.05^{b}	3.60±0.87^{b}
T_3	4.80±0.05^{b}	4.22±0.15^{b}	3.83±0.03^{b}	3.43±0.51^{b}
pH				
T_1	7.36±0.33^{a}	7.35±0.03^{a}	7.26±0.03^{a}	6.70±0.36^{b}
T_2	7.10±0.05^{b}	7.06±0.08^{b}	6.86±0.08^{b}	6.45±0.19^{b}
T_3	7.21±0.051^{ab}	6.85±0.08^{b}	6.93±0.06^{b}	8.00±0.65^{a}
Alkalinity (mg/L)				
T_1	207±3.71^{b}	215±3.21^{b}	221±2.02^{b}	239±4.5^{a}
T_2	204±2.84^{b}	208±2.90^{b}	219±0.57^{b}	183±7.31^{b}
T_3	245±2.88^{a}	253±4.09^{a}	254±7.3^{a}	251±7.00^{a}

Note: Values with same superscripts in a column do not differs significantly at $p<0.05$ (n=3)

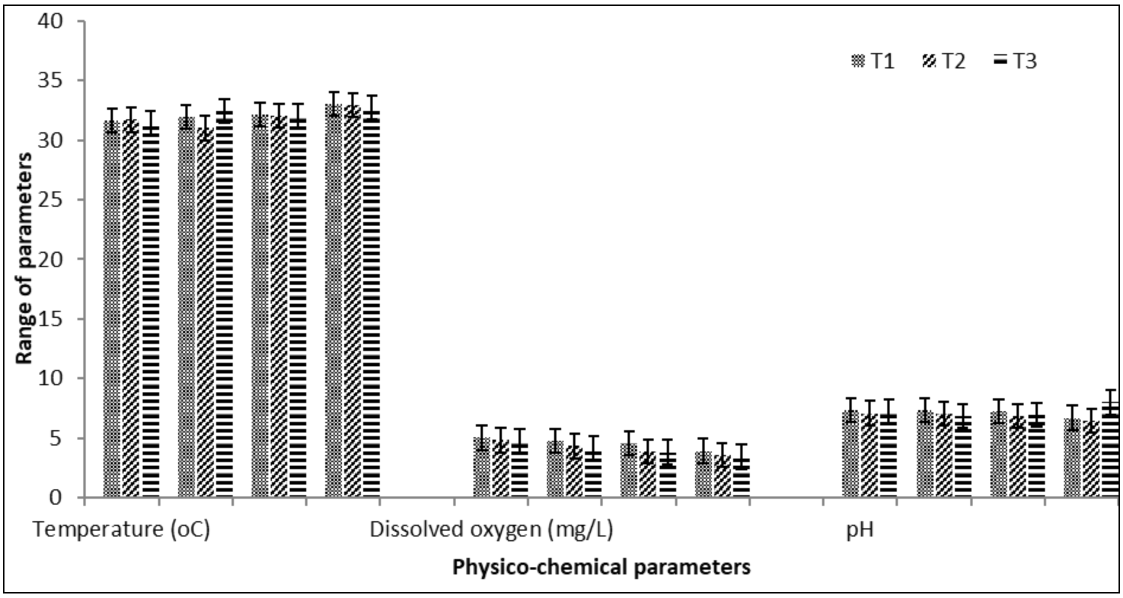

Fig 1: Variation of Physico-chemical parameters

Primary productivity

Primary productivity has varied significantly ($P<0.05$) between different treatments at various levels of dosages (Table 3). Highest primary productivity was observed when inorganic fertilizers were applied at 489.37mg (525.53±2.53 mgC/m^3) on 15th day of fertilization while the lowest was observed 82.63±0.93 mgC/m^3 when chicken drops were applied at lowest dosage (15gm). Significantly higher amount of primary productivity (521.86±2.59 mgC/m^3) was observed on 30th day of experiment in tanks fertilized with inorganic fertilizers applied followed by tanks fertilized with chicken droppings (423.33±8.25 mgC/m^3) at third level. On 60th day of experiment, again tanks fertilized with inorganic fertilizers showed maximum primary productivity (525.53±2.23 mgC/m^3) compared with other treatments. In comparison with organic fertilization, chicken droppings showed higher primary productivity (428.33±7.9 mgC/m^3) compared with cow dung on 60th day of experiment. The lowest primary productivity (T_3, Level 1) was observed wen tanks were fertilized with cow dung at 112.5 gm (Fig. 2 & 3).

Table 3: Primary productivity in different treatment groups on various days of sampling.

Days		15	30	45	60
T_1	Level 1	123±1.52^{e}	120.33±1.20^{e}	121.66±0.88^{e}	123±0.72^{f}
	Level 2	410±2.90^{b}	409.33±2.90^{bc}	410.33±2.90^{b}	410.67±2.61^{cb}
	Level 3	525.53±2.53^{a}	521.86±2.59^{a}	523.96±2.43^{a}	525.41±3.23^{a}
T_2	Level 1	136.66±1.45^{e}	134.66±1.45^{e}	134.66±1.45^{e}	136.67±1.32^{f}
	Level 2	391±4.58^{cb}	391±4.35^{cb}	390.66±4.33^{c}	391±4.21^{cd}
	Level 3	428.33±8.41^{b}	423.33±8.25^{b}	424.66±8.11^{b}	428.33±7.9^{b}
T_3	Level 1	82.63±0.93^{f}	81.26±0.93^{f}	215.33±0.33^{d}	82.63±0.11^{g}
	Level 2	353.33±17.63^{d}	352.33±17.45^{d}	214.33±0.88^{d}	353.33±0.72^{e}
	Level 3	376±0.57^{cd}	374±0.57^{cd}	221±0.57^{d}	376±0.43^{de}

Note: Values with same superscripts in a column do not differs significantly at $p<0.05$ (n=3)

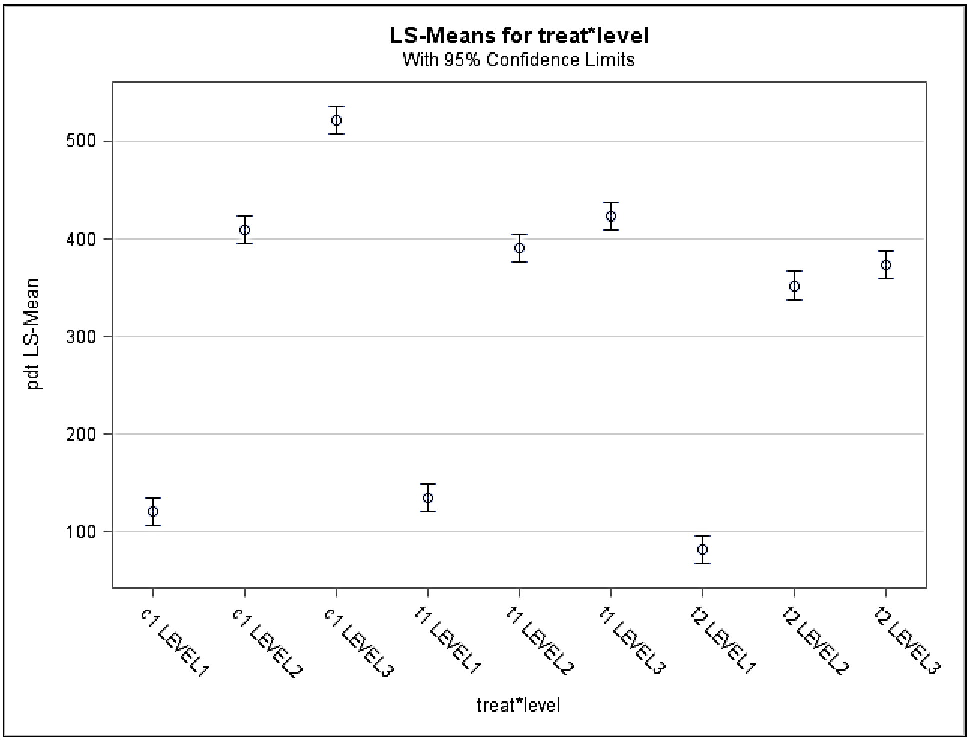

Fig 2: Interaction effect of productivity on 30th day of sampling

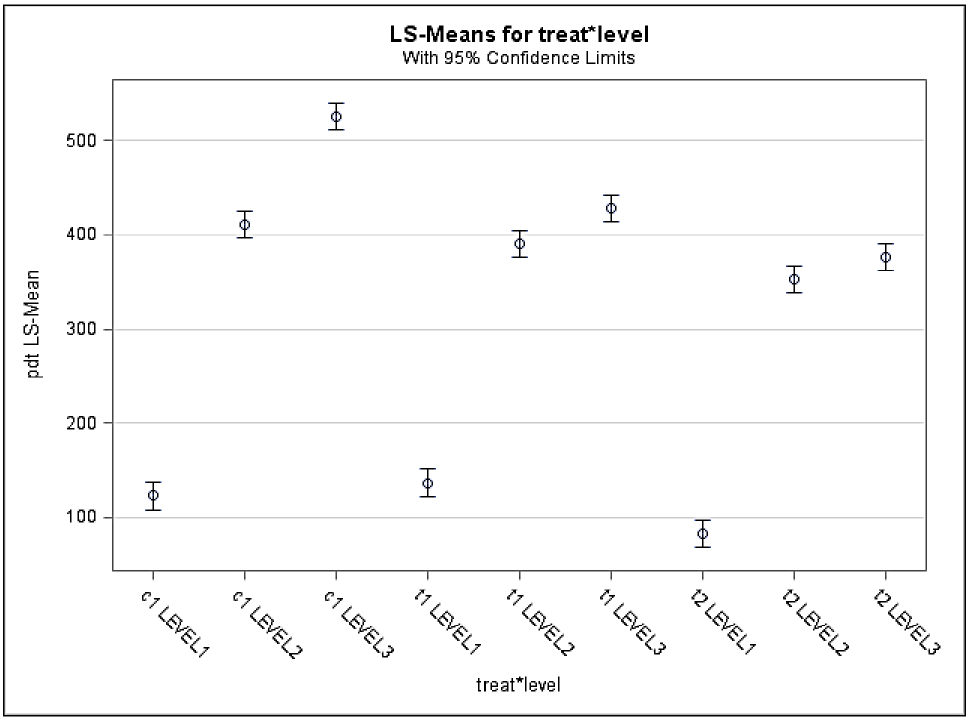

Fig 3: Interaction effect of productivity on 60th day of sampling

Discussion

Physico-chemical parameters

Temperature plays an important role in regulating metabolic rate of fish. The water temperatures observed during experimental period were within the range (26-32°C). Although, Diana [22] and Jenkins *et al.* [23] reported that 18°C was the optimum temperature for common carp as yet the fish can survive extended exposure upto 41°C. The best growth was observed at the range of 23-30°C.

Higher dose of fertilizer is directly proportional to the availability of dissolved oxygen and inversely proportional to carbon dioxide concentration during light and dark hours, respectively. During light hours, dissolved oxygen will increase and consequently carbon dioxide concentration reduces as phytoplankton absorbs carbon dioxide. In contrast, dissolved oxygen level reduces at higher rates during night hours as both planktonic groups absorb oxygen from the surroundings [5]. This phenomenon may cause fish mortality before sun rise. The dissolved oxygen level in this study ranged from 3.2 to 6.5 mg/L, which was within the acceptable range as reported by FAO [5]. Dissolved oxygen was reduced to 3.2 mg/L, which may be due to utilization by plankton and caused oxygen reduction during night hours. The common carp can survive in low oxygen concentration (<5mg/L) as well as at super saturation (<10mg/L) [12]. Boyd (1990) reported that the application of ammonium and urea-based fertilizers cause water acidification due to nitrification by producing two hydrogen ions from each ammonium ion. In the present study, the carbon dioxide concentration was undetectable and may be as a result of constant aeration in the experimental tanks.

The pH of culture water was one of the important indices of aquaculture yield. The pH of the water in which common carp fingerlings were reared, varied between 7.3 to 7.7, which was within the acceptable range [5]. De Urzedo *et al.* [24] reported that water quality parameters varied highly under the application of different doses of fertilizers as well as under passage of time period. According to Jatindra *et al.* [19], water temperature and pH ranged from 28.5-30°C and 7.5 to 8.22 in different treatments, respectively was found effective. In different treatment of their experiment, the concentration of dissolved oxygen in surface water varied between 2.8 and 18.8 mg/L and gradually increased in lesser fertilizer dose and decreased with further increase in fertilizer dose.

The total alkalinity of water depicts the measure of its capacity to neutralize the acids, caused by the salts of weak acids. Similarly, water hardness is the measure of capacity of the water for soap precipitation. It is caused by the presence of total concentration of divalent metallic cations like calcium, magnesium, ferrous, strontium, etc. The total alkalinity was found comparatively higher (183 to 264 mg/L) in all experimental tanks while the water hardness was recorded within the range of 200 to 320 mg/L. The favorable range of alkalinity for fresh water fish culture system is 50 to 275 mg/L and for hardness is 50 to 275 mg/L [25]. Its strength was in higher amount because the available water source was ground water coupled with the application of manures for fertilization.

Ahmed *et al.* [26] reported that the average of pH was about 7.0 in all treatments. The DO got never dropped below 5.0 mg/L during experiment. Carbonate alkalinity was observed only in the treatments manured with poultry litter for very limited periods, when free CO_2 in the treatments was absent. Keshavanath *et al.* [27] reported that water quality parameters monitored were within favorable limits for the growth of fish. Water pH was alkaline in both of their experiments and an increase in pH was noted following fertilization. This would have enabled faster degradation of organic matter as observed by Boyd [17].

Nutrients in different manures

Jha *et al.* [4] reported that the amount of total nitrogen in cow dung and poultry manure as 2.15% and 2.66%; whereas the amount of organic carbon was 21.24% and 30.19%, respectively. The primary objective of pond fertilization is to maintain an optimal nutrient concentration for sustainable biological production. Individual pond ecology determines how fertilization affects pond productivity, not the pond's physical location. There is no universal recipe of maximal fertilization rates due to pond-specific variability. Nutrients contents in cow dung and poultry manure such as Nitrogen, Carbon, Hydrogen and Sulphur were higher in poultry, 6.05%, 30.57%, 4.22% and 0.43%, respectively, while they were lower in cow dung which ranged, 0.86%, 9.78%, 1.74% and 0.215%, respectively.

Primary productivity

It is a rate at which photosynthetic and chemosynthetic autotrophs convert energy to organic substances. Total amount of productivity in system is gross primary productivity and net amount of energy plant accumulates during a time is net primary productivity. Though, the food chain directly flows carbohydrate to the herbivorous fish or through zooplankton which graze upon the phytoplankton to carnivorous fish. Thus, amount of primary productivity in the water body is directly proportional to the expected fish yield. The suitable range of primary productivity for fish culture was reported as 1000-3000 mg C/m^3/day [28].

Different inputs of mixed fertilizers per week *viz.* poultry droppings and cattle manure, single super phosphate and urea were analyzed by Jasmine *et al.* [12] in tanks at 105, 211, 422, 844, 1689, 3378 and 6757 g/4.5 m^3, with a fixed CNP ratio of 88.6:7.5:1 and a stocking density of 35,500 fish/ha. Advanced fry of *Catla catla* (1.2 gm), *L. bata* (0.99 gm) and *C. carpio* (1.3 gm) were introduced at the rate of 16 fish/tank (4:6:6). The results showed that fish production was directly proportional to fertilizer dose and showed maximum yield at 844 gm/tank/week at higher dose of fertilizers (6757 g/4.5 m^3). Critical evaluation of the data indicated four responses on the basis of fertilizer dose *viz.* poor growth of both fish and algae under first nutrient level (105-422 gm/tank/week); accelerated growth (>422 to 844 gm/tank/week) in second nutrient level; fish growth retarded (>844 to 1689 gm/tank/week) with continued algal growth observed in third nutrient level and poor growth of algae with total fish mortality at fourth nutrient level (>1689 to 6757 gm/tank/week). Phosphorous was the most important nutrient regulating the productivity of fish and in most cases, nitrogen was not considered as a limiting nutrient of pond productivity [16].

Conclusion

Aqua farming in extensive and semi-intensive system is quite costly if appropriate quantities of planktons are not available in the system. In the present experiment, effects of organic and inorganic fertilizers were standardized without affecting water quality parameters with highest primary production. The aim of the present experiment was fulfilled and standardized minimum effective dosage to gain maximum primary production for aquaculture production in extensive and semi-intensive systems. The subject matter in the manuscript will be helpful to small aqua farmers for getting higher production with lower input cost. However, due to organic matter a wide fluctuation was recorded over the experimental period.

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