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Effect of Pond Fertilization with Vermicompost and Some Other Manures on the Hydrobiological Parameters of Treated Pond Waters

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ABSTRACT
Organic fertilizers are used to enhance the productivity of inland aquatic resources. These fertilizers directly influence the water quality parameters which in turn form the aquatic environment. Vermicompost is a new introduction to the list of organic fertilizers used in aquaculture production. However, its effects on water quality parameters have not yet been fully investigated. To accomplish this objective, the present study was undertaken. The experiment was carried out in 5.54×6.15 m size ponds with a stocking density of 30 fish per pond in a ratio of 3:4:3 of Indian major carps viz. catla (*Catla catla* Ham.), rohu (*Labeto rahita* Ham.) and mrigal (*Cirrhinus mrigala* Ham.). Different organic fertilizers used as treatments were: untreated ponds as the control (T_1), pig manure at 4,000 kg ha^{-1} year^{-1} (T_2), poultry manure at 6,000 kg ha^{-1} year^{-1} (T_3), cow dung at 10,000 kg ha^{-1} year^{-1} (T_4), vermicompost at 10,000 kg ha^{-1} year^{-1} (T_5) and vermicompost at 15,000 kg ha^{-1} year^{-1} (T_6). One fourth dose of fertilizers was applied 15 days prior to the start of observations and remaining doses in equal amounts were given at fortnightly intervals. The water quality parameters like dissolved oxygen, pH, alkalinity, hardness, free carbon dioxide, nitrogen, potassium, phosphorous, temperature, turbidity and planktons were measured at monthly intervals. Pond waters treated with vermicompost at 10,000 kg ha^{-1} year^{-1} seemed to be the best among the six treatments. This was evident in case of DO, alkalinity, hardness, light penetration, free carbon dioxide, phytoplanktons and zooplanktons. For other parameters too, this treatment kept their values in the favorable ranges. On the basis of all permutations and combinations, therefore, vermicompost at 10,000 kg ha^{-1} year^{-1} came out to be the best among the six treatments used in this study. The results revealed that, except for temperature, values of all other water quality parameters in the treated ponds differed significantly between treatments as well as months. Despite this, the values of most of the chemical and physical parameters of all the treatments fell in the favorable ranges. Then, pond waters treated with vermicompost at 10,000 kg ha^{-1} year^{-1} (T_5), were found to have the best levels of quality parameters as compared to those in the other treatments.

Key words: Pond fertilization, water quality parameters, organic fertilizers, vermicompost

INTRODUCTION
To improve the productive efficiency of water resources and to have a maximum yield from such water bodies, it is necessary to treat them with suitable manures/fertilizers. Such fertilizers should assure a hygienic condition, should be ecologically feasible and economically viable and should

ensure maximum production in the shortest period (Bhakta *et al*., 2004). Fertilization of a fish pond actually increases the production of beneficial phytoplanktons, the microscopic free-floating algae, that act as the basis of aquatic food chain which, in turn, increase the amount of harvestable fish (Garg and Bhatnagar, 2000). The harvest of a fertilized pond can be increased 2.8 times that of an unfertilized pond (Conte, 2000; Wurts, 2004). Increasing level of fertilization increases all the water parameters in suitable ranges (Wahab *et al*., 1999), except for dissolved oxygen which shows variations at dawn on application of high manuring rate (Shevgoor *et al*., 1994). The physico-chemical factors like light penetration, pH, dissolved oxygen, carbonates, bicarbonates, total alkalinity, calcium, magnesium and total hardness contribute in increasing the dry weight of plankton biomass (Singh *et al*., 2000; Rafigue *et al*., 2003; Liti *et al*., 2006).

When organic fertilizers decompose in the water, varying amounts of nitrogen, phosphorous and potassium (N, P, K) are released. These serve as primary nutrients for the phytoplankton community (Wohlfarth and Schroeder, 1979). Organic fertilization also stimulates the growth of decomposers such as bacteria and fungi. Bacteria and fungi are critical to the breakdown of toxic waste products that can accumulate with the use of prepared feeds (Conte, 2000; Wurts, 2004). However, animal manure takes some time for its decomposition and release of nutrients in the body of water (Nath and Lannan, 1992). Beside this, higher doses as well as high ambient temperature may lead to eutrophication, which can make the water body unsuitable for fish culture by adversely altering its hydrobiological characteristics (Trussel, 1972; Emerson *et al*., 1975; Ram *et al*., 1982). Organic manures if not decomposed completely before application in aquaculture pond, may deteriorate the water quality as they utilize oxygen during decomposition. Therefore, the amount of any organic manure to be added in the pond mainly depends upon its biological oxygen demand, as its excessive use may cause severe dissolved oxygen depletion in the pond and results in production of toxic gases like CO_2, H_2S, NH_3 etc. and can spread parasitic diseases (Chakrabarty *et al*., 2008). Hence, to minimize the harmful effects of organic manures on pond ecosystem, the best alternative is to utilize fully decomposed/digested organic manures in comparison to undigested or semi digested organic manures.

Vermicompost is a product of vermi-biotechnology that is frequently used in agro-ecosystems as organic fertilizer (Saini *et al*., 2008a, b, 2010). It is a form of organic manure which can be produced from variety of organic wastes (cow dung, poultry waste, piggery waste, agriculture waste etc.) by earthworms and is made up of worm castings (fecal excretion) and other organic material (Reinecke and Alberts, 1987). Even if vermicompost dries up, there is no harm to its micro flora; hence, it is referred to as potential biological manure or biofertilizer. Vermicompost is found to be more nutritious than cow dung/farmyard manure in terms of more carbon and phosphorus, less potassium and comparable nitrogen (Shinde *et al*., 1992). Among the decomposed manures, vermicompost is rich in all types of major and minor nutrients, vitamins, enzymes, antibiotics, growth promoters etc. (Bhusan and Yadav, 2003). The advantage of use of vermicompost as organic fertilizer is the quick availability of nutrients in 'ready-to-uptake' forms (Nath and Lannan, 1992). Use of vermicompost as pond fertilizer is a new and recent addition to the fish culture practice. Sulochana *et al*. (2009) observed higher manorial value of vermicompost as compared to raw cow dung and poultry dropping in terms of its effect on the hydro-biology of treated waters. In the earlier study, we observed higher fish growth (Godara *et al*., 2015a) and lower number of bacterial fish pathogens (Godara *et al*., 2015b) in ponds treated with vermicompost as compared to cow dung, poultry and piggery manures. However, state of hydrobiological parameters in the treated ponds is considered to be the direct reflection of future primary and secondary productivity of such water bodies. Therefore, knowledge of effects of these manures on the hydrobiological parameters of treated waters is equally important. Such a knowledge at the moment is scanty and scarce. To accomplish this objective, the present study was proposed.

MATERIALS AND METHODS

Experimental set up/design: This study was carried out at the Fish Farm and Fisheries Biology Laboratory of Department of Zoology in Chaudhary Charan Singh Haryana Agricultural University, Hisar, India. The experiment was performed in fish ponds each with a size of 5.54×6.15 m from August, 2011 to August, 2012 (Godara *et al*., 2015a). The ponds were cleaned and the lime was applied at 200 kg ha^{-1} $year^{-1}$. These ponds were filled with inland ground water obtained from the deep tube wells and were allowed to stabilize for about 15 days. Three fish species of Indian major carps commonly used for composite fish culture in India, viz. catla (*Catla catla* Ham.)-a surface feeder, rohu (*Labeo rohita* Ham.)-a column feeder and mrigal (*Cirrihinus mrigala* Ham.)-a bottom feeder, were used for this experiment. The fishes were fed artificial diet as described by Godara *et al*. (2015a). The water level throughout the experiment was maintained at 1.54 m.

Treatments and pond fertilization: In this experiment, there were six different treatments each with four replications; the pond devoid of any fertilizer acted as the control (T_1). To fertilize the ponds, other five treatments included semi dried pig manure at 4,000 kg ha^{-1} $year^{-1}$ (T_2), poultry manure at 6,000 kg ha^{-1} $year^{-1}$ (T_3), cowdung at 10,000 kg ha^{-1} $year^{-1}$ (T_4), vermicompost at 10,000 kg ha^{-1} $year^{-1}$ (T_5) and vermicompost at 15,000 kg ha^{-1} $year^{-1}$ (T_6). In the beginning of experiment, initial dose equal to 25% of the total amount of the manure type was applied and remaining amount was given in equal split doses at fortnightly intervals (Godara *et al*., 2015a).

Analysis of water quality parameters of treated water: The water quality parameters were recorded at monthly intervals according to method described in APHA (1998). Following parameters were recorded.

Chemical and physical parameters of treated waters

Dissolved oxygen: Dissolved oxygen of treated water was measured at the collection site by modified Winkler's method. To the sample collected (without bubbling) in 250 mL glass stoppered bottles, 2 mL of manganese sulphate (Winkler's A) and 2 mL of alkaline Iodine-azide solution (Winkler's B) were poured at the bottom of the bottle to fix dissolved oxygen. It was thoroughly mixed and the flocculent precipitate was allowed to settle. Then 2 mL of concentrated sulphuric acid (H_2SO_4) was added through the side of the bottle and was shaken well to dissolve the precipitate. Subsequently, 50 mL of the above solution taken in a conical flask was titrated with 0.025 N sodium thiosulphate solution till pale straw colour appeared. To the latter, two or three drops of starch indicator solution (1%) were added and the sample was further titrated to colourless end point. The dissolved oxygen was determined from the following equation:

$$\text{Dissolved oxygen (mg L}^{-1}) = \frac{8\times 1000\times \text{N (0.025)}\times \text{V}_1}{\text{V}}$$

where, V is volume of the sample taken (mL), V_1 is volume of the titrant (sodium thiosulphate solution used in mL) and N is normality of the titrant.

Hydrogen ion concentration (pH): The pH of water was recorded by a digital pH meter (manufactured by Multiline F/set-3, Germany).

Alkanity: Total alkalinity was measured by methyl orange indicator method. The water samples for measurement of alkalinity were collected in plastic bottles and analyzed as possible to avoid denaturation. To a subsample of 50 mL in an Erlenmyer's flask, 0.1 mL methyl orange indicator was added and titrated against 0.02 N standard sulphuric acid to the end point that was slightly orange. Total alkalinity was estimated by using following equation:

$$\text{Total alkalinity (mg L}^{-1}\text{)} = \frac{\text{Volume of acid used (Normality of acid) (50,000)}}{\text{Volume of sample (mL)}}$$

Free carbon dioxide (CO^2): Two drops of phenolphthalein indicator was added to 50 mL of water sample taken in a flask. Then the sample solution was titrated against standard NaOH (0.02 N) until a slight pink color appeared:

$$\text{Free } CO_2 \text{ (mg L}^{-1}\text{)} = \frac{V_1}{V_2} \times 100$$

where, V_1 is volume of titrant used and V_2 is volume of sample taken.

Orthophosphate (o-PO_4): To the 25 mL of water sample taken in a conical flask, 1 mL of ammonia molybdate solution followed by 3 drops of freshly prepared stannous chloride was added. After 10 min, absorbance was read on spectrophotometer at 690 nm. Value of o-PO_4 was deduced from the standard curve prepared by dissolving 0.175 g of potassium dihydrogen phosphate in distilled water (0.2-1.0 mg L^{-1}).

Ammoniacal nitrogen (NH_4-N): Two drops of Rochelle salt solution was added to 50 mL of the filtered water sample taken in Erlenmeyer flask, which was followed by addition of 2 drops of Nesseler's reagent. After 10-20 min (colour development) absorbance was read at 425 nm against distilled water blank. The NH_4-N concentrations were calculated from the standard curve prepared by dissolving NH_4Cl (E Merck) in distilled water (dilution from 0.2-1.0 mg L^{-1}).

Potassium: Potassium of water was recorded directly by using a flame photometer.

Hardness: One milliliter ammonia buffer was added to 50 mL of water sample taken in conical flask and to the latter contents 3 drops of Eriochrome B-T indicator was added. The color of sample turned wine red. Then sample was titrated with standard EDTA solution, till the colour changed from wine red to blue. Total hardness was calculated with the help of following equation:

$$\text{Total hardness (mg L}^{-1}\text{)} = \frac{\text{Volume of EDTA solution used (mL)}}{\text{Volume of sample (50 mL)}} \times 100$$

Turbidity: The Secchi disk was dipped vertically in the water of treated pond by holding the graduated rope at the water surface. The readings were recorded, when Secchi disk disappeared and reappeared, while lowering and lifting the rope. The average of two readings gave the limit of visibility in water (transparence) that was expressed in centimeters (cm):

$$\text{Transparency (cm)} = \frac{A+B}{2}$$

where, A is depth at which Secchi disk disappears (cm) and B is depth at which Secchi disk reappears on lifting the rope (cm).

Temperature: The temperature of treated water was recorded by a thermometer (0-50°C).

Biological parameters of treated waters

Phytoplanktons and zooplanktons: Samples were collected by filtering 10 L of pond water through plankton net of 125 μm mesh size and concentrated to 40 mL in small plastic bottles. Plankton filtrate was then immediately preserved in 4% formalin. Plankton abundance was expressed as organisms per liter. The organisms were counted in Sedgwick rafter cell. One milliliter of concentrated plankton sample was transferred to the cell cavity. Planktons were allowed to settle and 10 randomly selected fields of chamber were counted under the microscope and number of planktons was calculated using equation as given below:

$$\text{No. of plankton (L)} = \frac{P \times C}{L} \times 100$$

where, P is number of planktons counted from ten aquaria, C is volume of final concentration of sample (mL) and L is volume of water sample (L) filtered.

Statistical analysis: The experiments were laid down in two factors Completely Randomized Design for Analysis of Variance (ANOVA). The values of Least Significant Differences (LSD) were derived and the treatment means were compared at 5% level of significance (Snedecor and Cochran, 1989).

RESULTS

Chemical and physical parameters of treated waters

Dissolved Oxygen (DO): The results of monthly variation in Dissolved Oxygen (DO) in the pond waters treated with different manures from August, 2011 to August, 2012 are presented in Table 1. In the ponds treated with vermicompost at 10,000 kg ha^{-1} $year^{-1}$, vermicompost at 15,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control, the ranges of the concentration of DO remained in the descending order between 4.76±0.02-6.81±0.02, 4.62±0.02-6.75±0.02, 4.54±0.03-6.70±0.04, 4.43±0.02-6.64±0.03, 4.30±0.01-6.55±0.03 and 4.12±0.01-6.45±0.02 mg L^{-1}, respectively. The concentration of DO for months as well as treatments differed significantly ($p<0.05$, ANOVA, Table 1). In the pond waters treated with vermicompost at 10,000 kg ha^{-1} $year^{-1}$, DO was found to be at maximal level as compared to those given other treatments. The minimal concentration of

Table 1: Monthly variation in dissolved oxygen and pH in pond waters treated with different manures from August, 2011-August, 2012

	Dissolved oxygen in different treatments (mg L^{-1})						pH in different treatments					
Months	T_1	T_2	T_3	T_4	T_5	T_6	T_1	T_2	T_3	T_4	T_5	T_6
August	5.23±0.01	5.36±0.02	5.42±0.01	5.48±0.01	5.81±0.01	5.63±0.02	7.50±0.13	7.50±0.15	7.60±0.11	7.70±0.08	7.81±0.11	7.90±0.07
September	5.43±0.01	5.52±0.02	5.55±0.02	5.66±0.01	5.88±0.01	5.74±0.02	7.65±0.15	7.71±0.11	7.82±0.07	7.91±0.04	8.00±0.07	8.32±0.09
October	5.61±0.02	5.72±0.03	5.70±0.01	5.83±0.03	6.02±0.02	5.93±0.02	7.72±0.07	7.80±0.91	7.93±0.11	8.00±0.07	8.12±0.09	8.51±0.04
November	5.85±0.03	5.92±0.03	5.95±0.04	6.01±0.02	6.19±0.03	6.12±0.03	7.81±0.07	7.90±0.09	8.00±0.11	8.13±0.07	8.24±0.09	8.64±0.04
December	6.08±0.01	6.13±0.04	6.18±0.03	6.21±0.03	6.42±0.04	6.36±0.04	7.60±0.04	7.70±0.07	7.86±0.04	7.91±0.07	8.00±0.04	8.20±0.04
January	6.29±0.04	6.38±0.02	6.43±0.01	6.46±0.02	6.65±0.04	6.55±0.05	7.60±0.07	7.80±0.07	7.90±0.05	8.04±0.06	8.11±0.04	8.35±0.06
February	6.45±0.02	6.55±0.03	6.64±0.03	6.70±0.04	6.81±0.02	6.75±0.03	7.73±0.07	7.90±0.05	8.00±0.06	8.10±0.06	8.22±0.07	8.42±0.04
March	6.27±0.00	6.34±0.04	6.42±0.02	6.46±0.03	6.62±0.01	6.51±0.02	7.81±0.06	7.90±0.11	8.04±0.04	8.15±0.05	8.20±0.05	8.50±0.04
April	5.15±0.02	4.60±0.02	4.84±0.02	5.00±0.03	5.20±0.02	5.40±0.01	7.80±0.05	7.98±0.07	8.16±0.09	8.11±0.07	8.34±0.09	8.60±0.07
May	4.20±0.02	4.62±0.01	4.90±0.02	5.10±0.02	5.30±0.01	5.86±0.02	7.80±0.06	8.00±0.09	8.18±0.05	8.20±0.07	8.30±0.08	8.61±0.09
June	4.12±0.01	4.30±0.01	4.43±0.02	4.54±0.02	4.76±0.02	4.62±0.02	8.00±0.09	8.00±0.06	8.20±0.11	8.30±0.04	8.41±0.07	8.73±0.06
July	4.24±0.02	4.61±0.03	4.82±0.02	4.92±0.02	5.10±0.01	5.00±0.01	8.10±0.07	8.10±0.07	8.30±0.07	8.32±0.07	8.44±0.13	8.80±0.05
August	5.20±0.01	5.42±0.02	5.45±0.02	5.73±0.01	5.90±0.01	5.80±0.01	8.10±0.07	8.20±0.04	8.30±0.09	8.40±0.11	8.50±0.09	9.00±0.07

Mean±SE of 4 replications, T_1: Control; T_2: Pig manure at 4,000 kg ha^{-1} $year^{-1}$, T_3: Poultry manure, at 6,000 kg ha^{-1} $year^{-1}$, T_4: Cow dung at 10,000 kg ha^{-1} $year^{-1}$, T_5: Vermicompost ;at 10,000 kg ha^{-1} $year^{-1}$ and T_6: Vermicompost at 15, 000 kg ha^{-1} $year^{-1}$, LSD (DO) for months = 0.83 ($p \le 0.05$), LSD (pH) for months = 0.55 ($p \le 0.05$), LSD (DO) for treatments = 0.13 ($p \le 0.05$), LSD (pH) for treatments = 0.15 ($p \le 0.05$)

DO was observed during June whereas, maximal concentration of DO was observed during February in all the treatments. From these results, it was evident that vermicompost at 10,000 kg ha^{-1} $year^{-1}$ was better than the other treatments in increasing the amount of DO in waters of treated ponds (Table 1).

Hydrogen ion concentration (pH): The results of monthly variation in pH in the pond waters treated with different manures from August, 2011 to August, 2012 are presented in Table 1. In the pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$ and pig manure at 4,000 kg ha^{-1} $year^{-1}$ treatments, the pH remained in between 7.90±0.07-9.00±0.07, 7.80±0.11-8.50±0.09, 7.70±0.08-8.40±0.11, 7.60±0.11-8.30±0.09 and 7.50±0.15-8.20±0.04, respectively. The pH for months as well as treatments differed significantly ($p<0.05$, ANOVA, Table 1). In the pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$, pH was at maximal level as compared to those given other treatments; pH in the control treatment was at the minimal level (7.50±0.03-8.10±0.07).

Alkalinity of the treated water: The results of monthly variation in alkalinity in the pond waters treated with different manures from August, 2011 to August, 2012 are presented in Table 2. The ranges of concentration of alkalinity of the pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control varied from 100.00±0.34-260.62±0.72, 90.00±0.40-200.00±0.94, 85.30±0.50-188.41±0.85, 80.00±0.40-158.20±0.85, 70.40±0.57-120.80±0.80 and 50.00±0.37-86.60±0.72 mg L^{-1}, respectively. The pond water alkalinity was at minimal level (50.00 mg L^{-1}) during December in the control treatment whereas, it was at maximal level during August (260.62 mg L^{-1}) in pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$ (Table 2). The mean values of alkalinity for months as well as treatments differed significantly ($p<0.05$, ANOVA, Table 1). Pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$ showed maximal increase in the concentration of alkalinity as compared to those with other treatments. Among the six treatments, the mean value of alkalinity in the control treatment was at minimal level. From these results, vermicompost at 15,000 seemed to be better than other treatments in controlling the alkalinity of pond waters.

Hardness of the treated water: The results of monthly variation in hardness in the pond waters treated with different manures from August, 2011 to August, 2012 are presented in Table 2. The ranges of total hardness for waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control were: 73.06±0.36-192.02±0.28, 69.00±0.51-141.20±0.67, 60.90±0.17-118.85±0.66, 55.08±0.41-113.00±0.59, 52.0±0.23-106.00±0.45 and 49.90±0.09-78.00±0.74 mg L^{-1},respectively. The minimal level of total hardness (50.90 mg L^{-1}) was during December in the pond waters having control treatment while, maximal level of total hardness (192.02 mg L^{-1}) was during August in the pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$. The mean values of hardness for months as well as treatments differed significantly ($p<0.05$, ANOVA, Table 1). Pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$ showed maximal increase in the hardness followed by vermicompost 10,000 kg ha^{-1} $year^{-1}$, cow dung 10,000 kg ha^{-1} $year^{-1}$, poultry manure at

Table 2: Monthly variation in alkalinity and hardness in pond waters treated with different manures from August, 2011-August, 2012

	Water alkalinity in different treatments (mg L^{-1})						Water hardness in different treatments (mg L^{-1})					
Months	T_1	T_2	T_3	T_4	T_5	T_6	T_1	T_2	T_3	T_4	T_5	T_6
August	51.60±0.29	75.74±0.47	82.00±0.41	85.30±0.50	90.00±0.40	100.00±0.34	50.10±0.17	52.00±0.23	57.95±0.38	60.90±0.17	69.00±0.51	73.06±0.36
September	53.09±0.40	83.21±0.36	84.00±0.40	87.00±0.45	92.23±0.63	110.00±0.36	52.80±0.31	55.08±0.32	60.40±0.35	64.20±0.29	70.40±0.56	77.10±0.41
October	56.00±0.50	85.02±0.56	91.55±0.66	95.54±0.62	105.08±0.39	112.40±0.35	55.60±0.18	60.02±0.31	68.60±0.27	70.00±0.40	85.01±0.40	88.60±0.69
November	58.00±0.54	99.70±0.50	100.23±0.45	107.24±0.47	112.05±0.53	115.80±0.77	58.03±0.72	65.52±0.22	71.80±0.45	75.00±0.40	90.26±0.57	100.60±0.48
December	50.00±0.37	70.40±0.57	80.00±0.40	100.04±0.45	131.60±0.72	110.30±0.50	50.90±0.09	52.60±0.55	55.08±0.41	60.00±0.40	95.80±0.41	110.10±0.14
January	51.80±0.45	87.00±0.57	90.58±0.70	110.08±0.41	142.70±0.38	150.60±0.62	53.04±0.40	58.80±0.51	62.69±0.45	70.10±0.41	104.08±0.07	120.08±0.27
February	53.20±0.77	90.51±0.64	100.50±0.62	120.82±0.46	165.01±0.47	177.00±0.40	58.16±0.49	59.04±0.37	68.00±0.28	80.09±0.38	109.26±0.33	134.10±0.48
March	54.20±0.64	100.53±0.37	110.00±0.76	130.85±0.30	170.91±0.44	187.80±0.82	60.00±0.46	60.00±0.31	72.10±0.40	97.00±0.33	116.02±0.42	140.04±0.53
April	55.40±0.35	113.41±0.72	120.82±0.79	150.00±0.58	176.80±0.52	200.10±0.51	66.10±0.41	70.20±0.37	82.00±0.45	100.00±0.24	120.02±0.64	151.50±0.40
May	60.00±0.41	116.20±0.77	130.80±0.47	160.44±0.69	180.52±0.63	211.65±0.53	71.95±0.81	82.07±0.88	90.09±0.88	108.08±0.67	126.03±0.91	164.03±0.42
June	67.51±0.63	117.52±0.64	140.50±0.64	170.52±0.66	189.00±0.76	230.05±0.64	73.60±0.33	94.20±0.77	100.00±0.27	110.00±0.41	132.00±0.24	177.40±0.59
July	70.00±0.62	119.36±0.64	151.00±0.89	182.00±0.57	190.05±0.73	250.02±0.81	75.04±0.40	100.02±0.30	106.02±0.36	115.02±0.40	135.03±0.70	180.16±0.70
August	86.60±0.72	120.80±0.80	158.20±0.85	188.41±0.71	200.00±0.94	260.62±0.72	78.20±0.74	106.00±0.45	113.00±0.59	118.85±0.66	141.20±0.67	192.02±0.28

Mean±SE of 4 replications, T_1: Control; T_2: Pig manure at 4,000 kg ha^{-1} $year^{-1}$, T_3: Poultry manure, at 6,000 kg ha^{-1} $year^{-1}$, T_4: Cow dung at 10,000 kg ha^{-1} $year^{-1}$, T_5: Vermicompost at 10,000 kg ha^{-1} $year^{-1}$ and T_6: Vermicompost at 15, 000 kg ha^{-1} $year^{-1}$, LSD (alkalinity) for months = 21.2, LSD (hardness) for months = 11.4 ($p \leq 0.05$), LSD (alkalinity) for treatments = 6.5 ($p \leq 0.05$), LSD (hardness) for treatments = 6.5 ($p \leq 0.05$)

6,000 kg ha^{-1} $year^{-1}$ and pig manure at 4,000 kg ha^{-1} $year^{-1}$; the hardness of waters in the control treatment was lowest among these six treatments. From these results, it seemed that vermicompost at 15,000 kg ha^{-1} $year^{-1}$ was better than vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control.

Temperature: The results of monthly variation in temperature of pond waters treated with different manures from August, 2011 to August, 2012 are presented in Table 3. The ranges of water temperature were 11.00±0.02-33.78±0.08, 10.40±0.04-33.70±0.09, 11.26±0.04-33.85±0.06, 11.35±0.02-34.00±0.08, 11.33±0.03-33.90±0.10 and 10.70±0.02-32.86±0.06°C in the pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control, respectively (Table 3). The water temperature was at minimal level during January while, it was at maximal level during August. Analysis of variance revealed that the differences between treatments were non-significant ($p>0.05$, ANOVA, Table 3) while highly significant differences were noticed among the months (LSD, $p<0.05$, Table 3).

Turbidity: The results of monthly variation in turbidity (light penetration) in the pond waters treated with different manures from August, 2011 to August, 2012 are presented in Table 3. The values of turbidity (light penetration) varied from 15.00±0.05-35.01±0.03, 16.30±0.05-35.96±0.05, 14.30±0.06-33.05±0.03, 14.00±0.05-32.01±0.04 and 13.00±0.06-30.25±0.02 cm in pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$ and pig manure at 4,000 kg ha^{-1} $year^{-1}$; the lowest values of light penetration was in the control treatment (10.70±0.02-32.86±0.06 cm). Vermicompost at 10,000 kg ha^{-1} $year^{-1}$ was found to give maximal light penetration in the pond waters followed by vermicompost at 15,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$ and pig manure at 4,000 kg ha^{-1} $year^{-1}$; the light penetration in the pond waters of control treatment was at minimal level. Statistically, there were significant differences between the months as well as treatments ($p<0.05$, ANOVA, Table 3). From these results, it seemed that vermicompost at 10,000 kg ha^{-1} $year^{-1}$ was better than vermicompost at 15,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$ and pig manure at 4,000 kg ha^{-1} $year^{-1}$ in light penetration; the lowest light penetration was in the water under the control treatment (Table 3).

Carbon dioxide (CO_2): The results of monthly variation in free carbon dioxide in the pond waters treated with different manures from August, 2011 to August, 2012 are presented in Table 4. In the pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$ and pig manure at 4,000 kg ha^{-1} $year^{-1}$, the ranges of concentration of free CO_2 remained 1.35±0.00-3.10±0.15, 1.10±0.00-3.00±0.17, 1.40±0.06-3.40±0.09, 1.37±0.00-3.30±0.10 and 0.97±0.00-2.84±0.10 mg L^{-1}, respectively. The differences between all the treatments as well as months were significant ($p<0.05$, ANOVA, Table 4). Pond waters treated with cow dung manure at 10,000 kg ha^{-1} $year^{-1}$, showed maximal concentration of free CO_2 followed by those treated with poultry manure at 6,000 kg ha^{-1} $year^{-1}$, vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$ and pig manure at 6,000 kg ha^{-1} $year^{-1}$; the concentration of free CO_2 in the

Table 3: Monthly variation in air, water temperature and turbidity in pond waters treated with different manures from August, 2011-August, 2012

Months	Air temp (°C)	Water temperature in different treatments (°C) T_1	T_2	T_3	T_4	T_5	T_6	Water turbidity in different treatments (cm) T_1	T_2	T_3	T_4	T_5	T_6
August	29.34	25.90±0.04	26.87±0.02	26.53±0.04	26.91±0.04	26.72±0.04	27.00±0.03	22.90±0.04	30.25±0.02	32.01±0.04	33.05±0.03	35.96±0.05	35.01±0.03
September	29.20	26.40±0.04	27.49±0.04	27.52±0.04	27.42±0.04	27.09±0.04	27.16±0.05	22.40±0.05	28.66±0.05	29.84±0.03	32.02±0.04	34.02±0.01	33.03±0.02
October	20.12	19.49±0.04	20.69±0.04	20.74±0.05	20.62±0.02	20.18±0.04	20.50±0.04	20.30±0.02	26.00±0.04	28.04±0.05	30.00±0.03	32.00±0.05	31.00±0.05
November	17.25	15.00±0.06	15.90±0.04	15.93±0.03	15.90±0.04	14.90±0.03	15.99±0.05	18.30±0.04	24.08±0.05	27.90±0.04	29.19±0.04	31.44±0.05	30.08±0.04
December	15.30	14.46±0.03	13.51±0.04	13.53±0.04	13.42±0.04	13.00±0.04	13.17±0.05	19.00±0.05	25.88±0.04	29.00±0.04	30.00±0.03	32.00±0.04	32.09±0.04
January	12.30	10.70±0.02	11.33±0.03	11.35±0.02	11.26±0.04	10.40±0.04	11.00±0.02	19.00±0.04	26.00±0.04	30.00±0.04	31.90±0.04	35.96±0.05	33.02±0.04
February	12.10	11.14±0.04	12.50±0.04	12.54±0.03	12.50±0.04	12.00±0.02	12.40±0.03	19.40±0.04	24.11±0.04	26.01±0.04	28.45±0.05	30.34±0.05	30.00±0.04
March	20.10	19.80±0.04	18.58±0.04	18.62±0.04	18.50±0.04	17.38±0.04	18.40±0.04	16.30±0.06	19.80±0.04	22.11±0.04	25.01±0.04	29.00±0.04	27.00±0.05
April	31.02	28.20±0.04	29.47±0.06	29.50±0.04	29.40±0.04	29.30±0.04	29.36±0.05	14.50±0.06	17.00±0.04	21.06±0.04	24.00±0.04	27.20±0.07	26.18±0.04
May	33.00	28.75±0.06	30.69±0.03	30.70±0.04	30.62±0.04	30.10±0.04	30.20±0.06	13.30±0.07	16.07±0.03	20.12±0.04	22.00±0.05	26.00±0.06	24.00±0.04
June	32.40	31.77±0.05	31.49±0.06	31.52±0.07	31.42±0.08	31.29±0.04	31.20±0.08	11.80±0.06	14.03±0.02	18.07±0.05	20.06±0.06	21.00±0.04	20.97±0.07
July	31.60	32.66±0.05	32.20±0.04	32.22±0.09	32.12±0.08	31.14±0.08	32.20±0.14	11.30±0.06	14.00±0.05	16.00±0.05	16.09±0.05	19.10±0.05	17.05±0.06
August	31.10	32.82±0.06	33.90±0.10	34.00±0.08	33.85±0.06	33.70±0.09	33.78±0.08	11.20±0.05	13.00±0.06	14.00±0.05	14.30±0.06	16.30±0.05	15.00±0.05

Mean±SE of 4 replications, T_1: Control; T_2: Pig manure at 4,000 kg ha^{-1} year^{-1}, T_3: Poultry manure, at 6,000 kg ha^{-1} year^{-1}, T_4: Cow dung at 10,000 kg ha^{-1} year^{-1}, T_5: Vermicompost at 10,000 kg ha^{-1} year^{-1} and T_6: Vermicompost at 15, 000 kg ha^{-1} year^{-1}, LSD (temp) for months = 1.4 ($p \le 0.05$), LSD (turbidity) for months = 2.6 ($p \le 0.05$), LSD (temp) for treatments = 2.1 ($p \ge 0.05$), LSD (turbidity) for treatments = 1.8 ($p \le 0.05$)

Table 4: Monthly variation in free CO_2 and potassium in pond waters treated with different manures from August, 2011-August, 2012

Months	Free CO_2 in different treatments (mg L^{-1}) T_1	T_2	T_3	T_4	T_5	T_6	Water potassium in different treatments (mg L^{-1}) T_1	T_2	T_3	T_4	T_5	T_6
August	0.76±0.01	0.97±0.00	1.37±0.00	1.40±0.06	1.10±0.000	1.35±0.00	2.03±0.03	2.09±0.03	3.24±0.02	3.13±0.02	2.01±0.04	3.07±0.05
September	0.82±0.01	1.33±0.01	1.48±0.01	1.50±0.10	1.38±0.000	1.40±0.01	4.53±0.03	12.66±0.05	16.38±0.06	12.30±0.04	10.00±0.04	11.49±0.04
October	0.95±0.07	1.40±0.01	1.54±0.06	1.60±0.09	1.45±0.010	1.48±0.00	5.90±0.05	15.34±0.05	19.27±0.04	13.17±0.05	11.14±0.03	12.59±0.06
November	1.39±0.01	1.43±0.00	1.60±0.10	1.70±0.07	1.48±0.050	1.52±0.06	6.85±0.06	16.91±0.06	19.38±0.05	14.39±0.04	12.37±0.05	13.14±0.03
December	1.10±0.01	1.20±0.00	1.70±0.04	1.80±0.04	1.30±0.010	1.60±0.06	4.17±0.05	18.04±0.03	19.18±0.04	11.86±0.05	13.11±0.04	11.60±0.04
January	1.15±0.01	1.18±0.00	2.98±0.06	2.00±0.11	1.22±0.000	1.86±0.00	4.46±0.05	18.73±0.04	21.36±0.05	11.76±0.05	13.15±0.06	11.60±0.04
February	1.30±0.01	1.51±0.00	2.10±0.10	2.20±0.12	1.57±0.000	1.97±0.07	5.06±0.05	18.34±0.05	21.39±0.05	12.98±0.04	13.22±0.04	12.00±0.07
March	1.80±0.01	2.26±0.06	2.57±0.02	2.65±0.16	2.36±0.050	2.40±0.04	6.54±0.04	18.37±0.08	21.68±0.04	13.40±0.04	13.32±0.03	13.27±0.05
April	2.04±0.05	2.41±0.06	2.80±0.08	2.86±0.08	2.52±0.110	2.60±0.08	6.70±0.07	18.42±0.06	21.73±0.04	14.63±0.04	13.30±0.07	13.83±0.05
May	2.20±0.07	2.58±0.10	2.98±0.07	3.07±0.08	2.69±0.140	2.80±0.08	7.08±0.04	18.79±0.04	21.80±0.07	16.48±0.06	13.60±0.07	14.22±0.04
June	2.30±0.07	2.62±0.12	3.04±0.13	3.10±0.10	2.71±0.130	2.86±0.05	7.19±0.04	18.88±0.08	23.06±0.06	17.64±0.06	13.86±0.05	14.86±0.05
July	2.40±0.08	2.69±0.09	3.18±0.12	3.31±0.10	2.80±0.017	2.91±0.09	7.56±0.06	19.06±0.06	23.30±0.07	18.79±0.05	14.07±0.06	15.46±0.05
August	2.50±0.08	2.84±0.10	3.30±0.10	3.40±0.09	3.00±0.170	3.10±0.15	7.78±0.05	19.98±0.07	23.94±0.05	18.86±0.06	14.27±0.05	15.65±0.06

Mean±SE of 4 replications, T_1: Control; T_2: Pig manure at 4,000 kg ha^{-1} year^{-1}, T_3: Poultry manure, at 6,000 kg ha^{-1} year^{-1}, T_4: Cow dung at 10,000 kg ha^{-1} year^{-1}, T_5: Vermicompost at 10,000 kg ha^{-1} year^{-1} and T_6: Vermicompost at 15, 000 kg ha^{-1} year^{-1}, LSD (CO_2) for months = 0.06 ($p \le 0.05$), LSD (K) for months = 0.03 ($p \le 0.05$), LSD (CO_2) for treatments = 0.13 ($p \le 0.05$), LSD (K) for treatments = 2.15 ($p \le 0.05$)

control treatment was found to be the lowest among these six treatments (in the range of 0.76±0.01-2.50±0.08 mg L^{-1}). The minimal concentration of free CO_2 (0.76 mg L^{-1}) was recorded in the control treatment during September while, maximal concentration (3.40 mg L^{-1}) of free CO_2 was recorded in cow dung at 10,000 kg ha^{-1} $year^{-1}$ during August (Table 4). From these results, it seemed that cow dung at 10,000 kg ha^{-1} $year^{-1}$ was better than poultry manure at 6,000 kg ha^{-1} $year^{-1}$, vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control (Table 4).

Potassium: The results of monthly variation in potassium in the pond waters treated with different manures from August, 2011 to August, 2012 are presented in Table 4. The ranges of total concentration of potassium were recorded as 3.07±0.05-15.65±0.06, 2.01±0.04-14.27±0.05, 3.13±0.02-18.86±0.06, 3.24±0.02-23.94±0.05, 2.09±0.03-19.98±0.07 and 2.03±0.03-7.78±0.05 mg L^{-1} for the pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$ and pig manure at 4,000 kg ha^{-1} $year^{-1}$ and control, respectively. The minimal value of potassium was recorded in the control (2.03 mg L^{-1}) during September while, maximal concentration (23.94 mg L^{-1}) of potassium was recorded in pond waters treated with poultry manure at 6,000 kg ha^{-1} $year^{-1}$ during August (Table 4). The pond waters treated with poultry manure at 6,000 kg ha^{-1} $year^{-1}$ were found to show maximal concentration of potassium followed by pond waters treated with pig manure at 4,000 kg ha^{-1} $year^{-1}$, cow dung 10,000 kg ha^{-1} $year^{-1}$, vermicompost 10,000 kg ha^{-1} $year^{-1}$ and vermicompost 15,000 kg ha^{-1} $year^{-1}$; the concentration of potassium in pond waters under control treatment was found to be the lowest among these six treatments (in the range of 2.03±0.03-7.78±0.05 mg L^{-1}). The difference between all the treatments as well as months were significant ($p<0.05$, ANOVA, Table 4). From these results, it seemed that poultry manure at 6,000 kg ha^{-1} $year^{-1}$ was better than pig manure at 4,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$ and vermicompost at 15,000 kg ha^{-1} $year^{-1}$ in increasing the amount of potassium in the pond waters; there was minimal potassium in the pond waters under the control treatment (Table 4).

Ammoniacal nitrogen (NH_4-N): The results of monthly variation in ammoniacal nitrogen in the pond waters treated with different manures from August, 2011 to August, 2012 are presented in Table 5. The ranges of concentration of NH_4-N was recorded as 0.082±0.001-0.140±0.004, 0.077±0.002-0.135±0.003, 0.090±0.000-0.170±0.003, 0.058±0.001-0.081±0.002, 0.041±0.001-0.070±0.001 and 0.027±0.000-0.050±0.002 mg L^{-1} in the pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control, respectively. The minimal concentration of NH_4-N (0.027 mg L^{-1}) was recorded in the pond waters under control treatment during September while, maximal concentration (0.140 mg L^{-1}) was recorded in the pond waters treated with cow dung at 10,000 kg ha^{-1} $year^{-1}$ in August (Table 5). The latter treatment was found to cause maximal increase in the concentration of NH_4-N in the pond waters followed by vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control; the concentration of NH_4-N in pond waters under the latter treatment was found to be the lowest among these six treatments (in the range of 0.027±0.000-0.050±0.004 mg L^{-1}). The differences between all the months as well as treatments were significant ($p<0.05$, ANOVA, Table 5). From these results, it seemed that cow dung at 10,000 kg ha^{-1} $year^{-1}$ was better than vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control in increasing the ammoniacal nitrogen in the treated pond waters.

Phosphorous: The results of monthly variation in phosphorus in the pond waters treated with different manures from August, 2011 to August, 2012 are presented in Table 5. The ranges of concentration of phosphorous was 0.070±0.001-0.186±0.004, 0.044±0.002-0.182±0.002, 0.035±0.002-0.175±0.002, 0.072±0.002-0.199±0.002, 0.029±0.001-0.089±0.001 and 0.019±0.001-0.047±0.002 mg L^{-1} in pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control, respectively. The minimal concentration of phosphorous (0.019 mg L^{-1}) was recorded in the waters under the control treatment during September while, maximal concentration (0.199 mg L^{-1}) of phosphorous was recorded in waters treated with poultry manure at 6,000 kg ha^{-1} $year^{-1}$ in August (Table 5). The latter treatment increased the concentration of Phosphorus to the maximal level followed by vermicompost at 10,000 kg ha^{-1} $year^{-1}$, vermicompost at 15,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control; the concentration of phosphorous in the latter treatment was found to be the lowest (in the range of 0.019±0.001-0.047±0.002 mg L^{-1}) among these six treatments. The differences between all the months as well as treatments were significant ($p<0.05$, ANOVA, Table 5). From these results, it seemed that poultry manure at 6,000 kg ha^{-1} $year^{-1}$ was better than vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$ and pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control in increasing the amount of phosphorous in the pond waters.

Abundance of phytoplanktons: The results of monthly variation in the abundance of phytoplanktons in the pond waters treated with different manures from August, 2011 to August, 2012 are presented in Table 6. The ranges of abundance of phytoplanktons were 90±1.47-4,839±5.00, 99±2.88-5,786±5.17, 80±4.39-3,510±5.16, 66±4.81-2,988±6.05, 53±4.00-1,122±5.05 and 44±4.69-870±6.41 no L^{-1} in the pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control, respectively. The differences between the treatments as well as months were significant ($p<0.05$, ANOVA, Table 6). The minimal number of phytoplanktons (85 no L^{-1}) was recorded in the control treatment during September while, maximal number of phytoplanktons (2,046 no L^{-1}) was recorded in pond waters treated with vermicompost at 10,000 kg ha^{-1} $year^{-1}$ during August (Table 6). Vermicompost at 10,000 kg ha^{-1} $year^{-1}$ was found to be the best among the six treatments producing maximal number of phytoplanktons followed by vermicompost at 15,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control; the number of phytoplanktons in the latter treatment was the lowest among the six treatments (in the range of 85±2.88-686±8.63 no L^{-1}). From these results, vermicompost at 10,000 kg ha^{-1} $year^{-1}$ seemed to be better than vermicompost at 15,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control in increasing the number of phytoplanktons in the treated pond waters.

Table 5: Monthly variation in nitrogen and phosphorous in pond waters treated with different manures from August, 2011-August, 2012

	Water nitrogen in different treatments (mg L^{-1})						Water phosphorous in different treatments (mg L^{-1})					
Months	T_1	T_2	T_3	T_4	T_5	T_6	T_1	T_2	T_3	T_4	T_5	T_6
August	0.027±0.000	0.041±0.001	0.058±0.001	0.090±0.000	0.077±0.002	0.082±0.001	0.019±0.001	0.029±0.001	0.072±0.002	0.035±0.002	0.044±0.002	0.070±0.001
September	0.038±0.001	0.041±0.001	0.069±0.001	0.109±0.001	0.080±0.001	0.083±0.001	0.020±0.001	0.030±0.001	0.114±0.001	0.040±0.002	0.067±0.002	0.086±0.001
October	0.039±0.001	0.045±0.002	0.069±0.001	0.114±0.001	0.085±0.001	0.091±0.001	0.024±0.002	0.035±0.001	0.141±0.001	0.047±0.002	0.095±0.002	0.099±0.003
November	0.041±0.001	0.051±0.001	0.072±0.001	0.120±0.001	0.099±0.001	0.111±0.001	0.032±0.002	0.037±0.002	0.153±0.002	0.070±0.001	0.128±0.003	0.132±0.001
December	0.035±0.001	0.044±0.001	0.061±0.001	0.127±0.000	0.102±0.001	0.113±0.000	0.010±0.000	0.040±0.000	0.159±0.001	0.050±0.000	0.056±0.002	0.137±0.001
January	0.039±0.001	0.048±0.001	0.063±0.002	0.133±0.001	0.111±0.001	0.117±0.001	0.012±0.001	0.050±0.001	0.160±0.001	0.120±0.001	0.130±0.001	0.139±0.001
February	0.037±0.002	0.050±0.001	0.070±0.001	0.139±0.001	0.115±0.002	0.119±0.001	0.019±0.001	0.055±0.001	0.172±0.001	0.140±0.001	0.142±0.001	0.149±0.001
March	0.038±0.001	0.053±0.002	0.071±0.002	0.145±0.002	0.117±0.001	0.123±0.002	0.023±0.001	0.068±0.001	0.173±0.002	0.146±0.002	0.150±0.001	0.154±0.002
April	0.040±0.001	0.057±0.002	0.072±0.002	0.150±0.002	0.119±0.002	0.127±0.001	0.028±0.001	0.072±0.002	0.180±0.002	0.161±0.002	0.162±0.002	0.167±0.002
May	0.041±0.001	0.062±0.002	0.073±0.002	0.158±0.002	0.125±0.002	0.131±0.002	0.032±0.001	0.081±0.002	0.186±0.002	0.161±0.002	0.174±0.002	0.170±0.002
June	0.043±0.002	0.065±0.002	0.075±0.002	0.160±0.002	0.128±0.002	0.135±0.002	0.035±0.002	0.083±0.002	0.190±0.002	0.166±0.002	0.175±0.001	0.172±0.001
July	0.045±0.002	0.066±0.004	0.076±0.002	0.167±0.002	0.130±0.002	0.137±0.002	0.042±0.002	0.085±0.002	0.195±0.003	0.170±0.002	0.179±0.002	0.180±0.002
August	0.050±0.002	0.070±0.001	0.081±0.002	0.170±0.003	0.135±0.003	0.140±0.004	0.047±0.002	0.089±0.001	0.199±0.002	0.175±0.002	0.182±0.002	0.186±0.004

Mean±SE of 4 replications, T_1: Control; T_2: Pig manure at 4,000 kg ha^{-1} year^{-1}, T_3: Poultry manure, at 6,000 kg ha^{-1} year^{-1}, T_4: Cow dung at 10,000 kg ha^{-1} year^{-1}, T_5: Vermicompost at 10,000 kg ha^{-1} year^{-1} and T_6: Vermicompost at 15, 000 kg ha^{-1} year^{-1}, LSD(N) for months = 0.01 ($p \leq 0.05$), LSD(P) for months = 0.001 ($p \leq 0.05$), LSD(N) for treatments = 0.19 ($p \leq 0.05$), LSD(P) for treatments = 0.15 ($p \leq 0.35$)

Table 6: Monthly variation in abundance of zooplanktons and phytoplanktons in pond waters treated with different manures from August, 2011-August, 2012

	Abundance of zooplanktons in different treatments (no L^{-1})						Abundance of phytoplanktons in different treatments (no L^{-1})					
Time period	T_1	T_2	T_3	T_4	T_5	T_6	T_1	T_2	T_3	T_4	T_5	T_6
August	85.2±2.9	82.4±4.8	90.0±4.1	137.0±4.8	183.8±5.1	142.0±5.2	44.0±4.7	53.4±4.0	66.2±4.8	80.3±4.4	99.1±2.9	90.2±1.5
September	91.8±4.2	119.4±4.1	370.8±3.6	482.6±4.5	820.0±7.1	510.2±6.8	104.2±3.4	170.4±4.2	282.6±4.8	318.7±4.7	541.9±4.2	365.4±6.5
October	94.4±2.4	515.0±7.5	724.0±7.3	736.2±4.7	1,025.7±6.5	830.5±5.2	190.6±4.1	278.0±5.1	423.0±5.8	502.1±2.6	809.0±5.3	537.0±5.2
November	98.0±1.8	850.0±3.2	870.0±10.3	903.8±5.8	1,116.4±7.2	981.6±6.7	205.0±4.2	322.4±4.9	721.1±4.3	740.2±4.5	1,205.2±6.5	1,030.0±5.7
December	78.1±3.7	104.3±3.7	188.2±4.5	1,011.9±4.3	1,235.0±3.7	1,110.8±5.5	124.8±4.3	185.8±6.5	390.8±4.8	836.4.6±4.9	1,837.3±3.9	1,765.2±2.1
January	88.4±3.6	410.6±5.5	487.0±5.1	1,184.0±5.9	1,305.1±4.0	1,189.3±4.4	156.6±3.8	224.4±5.5	460.6±4.5	1,025.8±4.9	2,558.6±4.8	2,396.4±4.3
February	107.0±5.8	1,006.2±3.2	1,030.0±4.9	1,199.1±5.7	1,420.8±5.2	1,280.6±4.5	230.0±4.8	280.4±4.1	1,020.4±4.9	1,448.9±4.7	2,844.8±4.5	2,776.0±5.7
March	114.8±3.2	1,108.0±4.7	1,122.1±8.0	1,230.3±3.3	1,552.4±4.5	1,387.5±5.6	298.2±6.9	408.0±4.4	1,806.3±4.9	1,992.2±3.9	3,280.4±4.4	3,045.8±5.3
April	130.0±4.7	1,126.1±5.8	1,178.3±2.4	1,280.5±7.3	1,681.8±4.3	1,535.2±5.2	310.4±5.6	553.2±4.7	2,051.2±5.4	2,272.1±6.3	3,724.2±4.5	3,394.6±3.9
May	224.6±5.8	1,180.0±7.4	1,328.7±3.6	1,370.4±4.1	1,790.0±4.6	1,688.4±4.8	362.8±5.6	623.1±5.3	2,220.6±4.3	2,437.4±5.2	4,134.6.0±5.7	3,878.4±4.9
June	344.0±6.6	1,232.6±6.4	1,388.4±5.2	1,487.1.4±5.3	1,850.6±4.8	1,705.6±4.5	490.6±6.9	831.6±4.2	2,360.4±5.1	2,768.6±4.8	4,648.4±4.8	4,352.6±4.9
July	550.6±7.4	1,288.4±8.7	1,500.0±6.4	1,567.0±3.7	1,952.3±3.6	1,753.0±2.8	692.0±5.9	918.5±4.7	2,769.5±4.9	3,076.0±5.7	5,210.0±5.5	4,628.2±5.4
August	686.0±8.6	1,345.0±3.9	1,569.0±7.4	1,683.0±6.7	2,046.0±4.0	1,790.2±4.5	870.1±6.4	1,122.0±5.1	2,988.2±6.1	3,510.4±5.2	5,786.6±5.7	4,839.0±5.0

Mean±SE of 4 replications, T_1: Control; T_2: Pig manure at 4,000 kg ha^{-1} year^{-1}, T_3: Poultry manure, at 6,000 kg ha^{-1} year^{-1}, T_4: Cow dung at 10,000 kg ha^{-1} year^{-1}, T_5: Vermicompost at 10,000 kg ha^{-1} year^{-1} and T_6: Vermicompost at 15, 000 kg ha^{-1} year^{-1}, LSD (zoo) for months = 0.83 ($p \leq 0.05$), LSD (phyto) for months = 0.55 ($p \leq 0.05$), LSD (zoo) for treatments = 178 ($p \leq 0.05$), LSD (phyto) for treatments = 337 ($p \leq 0.05$)

Abundance of zooplanktons: The results of monthly variation in the abundance of zooplanktons in the pond waters treated with different manures from August, 2011 to August, 2012 are presented in Table 6. The ranges of number of zooplanktons per liter were 142±5.22-1,790±4.16, 183±5.06-2,046±4.02, 137±4.78-1,683±6.69, 90±4.08-1,569±7.41, 82±4.78-1,345±3.93 and 85±2.88-686±8.63 in the pond waters treated with vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control, respectively. The differences between the treatments as well as months were significant ($p<0.05$, ANOVA, Table 6). The minimal number of zooplanktons (85 no L^{-1}) was recorded in the pond waters under the control treatment during September while, maximal number of zooplanktons (2,046 no L^{-1}) was recorded in pond waters treated with vermicompost at 10,000 kg ha^{-1} $year^{-1}$ during August (Table 6). Vermicompost at 10,000 kg ha^{-1} $year^{-1}$ was found to be the best among the six treatments giving maximal number of zooplanktons followed by vermicompost at 15,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control; the number of zooplanktons in the latter treatment was found to be the lowest (in the range of 85±2.88-686±8.63 no L^{-1}). From these results, it seemed that vermicompost at 10,000 kg ha^{-1} $year^{-1}$ was better than vermicompost at 15,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control in increasing the number of zooplanktons in the treated pond waters.

DISCUSSION

Various chemicals dissolved in water, its temperature and other physical factors together form what is called water quality parameters. Better the water quality parameters better would be the survival, growth and reproduction of fish. Therefore, for an aquatic ecosystem, changes in water characteristics that improve or reduce the water quality would respectively enhance or reduce the production of an aquatic crop (Diana and Lin, 1998). Effects of water quality parameters on the aquatic biota are governed by the Liebig's law of minimum (Liebig, 1840) and Shelford's law of tolerance (Shelford, 1913). There are some chemicals that must be in minimum quantity (Liebig, 1840) and still others, that should be present in the favorable limits (Shelford, 1913) to keep the ecological process going on. Bhatnagar and Devi (2013) enlisted the acceptable ranges of water quality parameters (Table 7). According to these researchers, the favorable ranges of different water parameters are: 3-5 mg L^{-1} Dissolved Oxygen (DO), 7-9.5 pH, 50-200 mg L^{-1} alkalinity, 75-150 mg L^{-1} hardness, 15-35°C temperature, 30-80 cm turbidity, 0-10 mg L^{-1} carbon dioxide and 0-0.05 mg L^{-1} ammoniacal nitrogen.

Table 7: Ranges of water quality parameters in the ponds for high fish yield (modified from Bhatnagar and Devi, 2013)

Parameters	Favorable range	Desirable range	Stress
Temperature (°C)	15-35	20-30	<12, >35
Turbidity (cm)	30-80	<12, >80	
Dissolved oxygen (mg L^{-1})	3-5	5	<3, >8
CO_2 (mg L^{-1})	0-10	<5	>12
pH	7-9.5	6.5-9	<4, >11
Alkalinity (mg L^{-1})	50-200	25-100	<20, >300
Hardness (mg L^{-1})	>20	75-150	<20, >300
Calcium (mg L^{-1})	4-160	25-100	<10, >250
Ammonia (mg L^{-1})	0-0.05	0- <0.025	>0.3
Plankton (No. L^{-1})	2000-6000	3000-4500	<3000, >7000

The DO in the water body is an important factor for the growth and survival of fish. In the treatments of this experiment, this condition for DO holds good during summer months; however, during winter months the concentration of DO remained little higher than the favourable range. Vermicompost at 10,000 kg ha^{-1} $year^{-1}$ gave the best concentration of DO among the six treatments of this study.

Each aquatic organism has its maximum and minimum toleration range of pH. The pH of most natural waters ranges between 5 and 10 (Boyd, 1990) and it changes according to the influence of many factors such as acid rain, pollution, CO_2 from the atmosphere and fish respiration. The decay of organic matter and oxidation of compounds in bottom sediments also affect pH in water bodies. In ponds, phytoplanktons and other organic plants use CO_2 during photosynthesis, so the pH of a water body rises during the day and drops at night. In the present study, a significant difference in pH was observed between all the treatments. Though, vermicompost at 15,000 kg ha^{-1} $year^{-1}$ seemed to be better than vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control, yet the pH in all the treatments remained in favourable ranges.

The quantity of base present in water is expressed as total alkalinity. Common bases found in fish ponds include carbonates, bicarbonates, hydroxides, phosphates and borates. Carbonates and bicarbonates are the most important components of alkalinity in pond waters. Natural water bodies in tropical areas exhibit a wide range of fluctuation in total alkalinity which depends on the population of primary and secondary producers, seasons, location and nature of bottom soil (Mandal, 1976). However, for a higher production of planktons, alkalinity must be in the favorable range. In the present study, except for vermicompost at 15,000 kg ha^{-1} $year^{-1}$ from May to August, the peak period of fish growth (Godara *et al*., 2015a), alkalinity of pond waters treated with all other manures remained in the favorable ranges. Kaur and Ansal (2010) also reported significantly higher alkalinity in the water treated with vermicompost as compared to other organic manure (cow dung).

The hardness of water is generally due to the presence of salts of calcium and magnesium. Hardness is also caused by the presence of carbonates and bicarbonates. The hardness of water plays an important role in the distribution of aquatic organisms. In the present study, except for vermicompost at 15,000 kg ha^{-1} $year^{-1}$ from May to August, the peak period of fish growth (Godara *et al*., 2015a), hardness of pond waters treated with all other manures remained in the favorable ranges.

Water temperature has prominent effect on growth rate, feed consumption and other metabolic functions of the organisms. Osborne and Riddle (1999) observed that fish growth parameters in terms of weight gain, feeding rate and feeding efficiency of grass carp showed an increasing trend with the increase in water temperature. As the sun shines over the surface of water, it starts absorbing heat and water becomes warm; the latter condition directly influences the physiological and metabolic activities of fish i.e., swimming, breathing, growth and reproduction (Jhingran, 1982). In the present study, temperature differences between treatments were non-significant. However, significant differences between the treatment means were observed during different months. The overall range of water temperature was 10.70-34.00°C. Except for four months of winter, the water temperature remained in the favorable range.

Light penetration is very crucial in the aquatic ecosystem because light regulates the primary production of the water body. Since, water often has many suspended materials, it is obvious that these materials would obstruct the light and hence, cannot reach the bottom. Thus, shallow ponds receive light up to bottom resulting in an abundant growth of phytoplanktons. These ultimately form a healthy food chain. In the present study, significant differences were observed in turbidity between different treatments. The light penetration was found to be maximal in vermicompost at 10,000 kg ha^{-1} $year^{-1}$ followed by vermicompost at 15,000 kg ha^{-1} $year^{-1}$, cowdung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$ and pig manure at 4,000 kg ha^{-1} $year^{-1}$. Therefore, water treated with vermicompost at 10,000 kg ha^{-1} $year^{-1}$ seemed to have more light penetration than the water treated with other manures and the control, despite the fact that the light penetration in all the treatments was in favorable ranges.

Free CO_2 released during the break down of organic matter is then utilized by phytoplanktons to produce oxygen which leads to more growth of fishes. The marked increase in water temperature was observed after February, which was responsible to accelerate decomposition of organic inputs (Poultry manure, pig manure and cow dung). During these warm months the release of CO_2 for photosynthesis was maximum, which enhanced the planktonic biomass. In the present study, significant differences were observed in free CO_2 between the treatments. Pond waters treated with cow dung manure at 10,000 kg ha^{-1} $year^{-1}$ showed maximal concentration of free CO_2 followed by those treated with poultry manure at 6,000 kg ha^{-1} $year^{-1}$, vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$ and pig manure at 6,000 kg ha^{-1} $year^{-1}$; the concentration of free CO_2 in control treatment was found to be the lowest among these six treatments. However, free CO_2 of pond waters treated with all the manures remained in the favorable ranges.

Potassium is present in pond and natural waters as compounds of sylvite (KCl), carnalite ($KCl\,MgCl_2.\,6H_2O$), potassium sulphate (KSO_4) and potassium nitrate (KNO_3). It is imperative that low contents of potassium result in poor growth rate that is linked to high rate of respiration causing depletion of oxygen. In the present study, significant differences in potassium were observed between the treated waters. Poultry manure at 6,000 kg ha^{-1} $year^{-1}$ was found to show maximal concentration of potassium in the pond waters followed by pig manure at 4,000 kg ha^{-1} $year^{-1}$, cow dung 10,000 kg ha^{-1} $year^{-1}$, vermicompost 10,000 kg ha^{-1} $year^{-1}$ and vermicompost 15,000 kg ha^{-1} $year^{-1}$, the concentration of potassium in the control treatment was found to be the lowest among these six treatments (Table 4).

The major source of nitrogen (up to 90%) in an aquaculture system is from fish feeds and is produced through the normal metabolic processes of the fish. Most of the nitrogen in organic matter exists as the amino acids in protein. The form of nitrogen will affect the processes in the aquatic ecosystem. In aquaculture ponds, high levels of fish and shellfish metabolism results in the production of various nitrogenous wastes. The major nitrogen containing substance released by these organisms is ammonia (NH_3), which reacts with water to become the soluble ammonium ion NH_4^+. Both NH_3 and NH_4^+ are fairly toxic to aquatic organisms, as is nitrite ion (NO_2^-) and its aqueous counterpart, nitrous acid (HNO_2). Through bacterial activity, ammonia and nitrite are metabolized to yield nitrate (NO_3^-), which is fairly safe for aquatic organisms and useful to phytoplanktons as a nutrient source. The nitrogen cycle in aquaculture ponds is the most important biogeochemical cycle of these systems. Nitrogen is essential to sustaining high primary production, but can also be toxic to many organisms in high concentrations. The correct balance of available nutrient and controlled wastes is necessary in any aquaculture system. In the present study, a significant difference in NH_4-N was observed between all the six treatments. Cow dung at 10,000 kg ha^{-1} $year^{-1}$ was found to cause maximal increase in the concentration of the NH_4-N in the pond waters followed by vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000 kg ha^{-1} $year^{-1}$, pig manure at 4,000 kg ha^{-1} $year^{-1}$

and the control; the concentration of NH_4-N in control treatment was found to be the lowest among these six treatments (Table 5). However, NH_4-N of pond waters treated with all the manures remained in the favorable ranges. Hassan *et al.* (2000a, b) too reported the level of NH_4-N in the ponds under the control treatment equivalent to 0.050 mg L^{-1}.

Phosphorous is one of the most common phytoplankton growth limiting elements. Phytoplanktons are only able to use phosphorous in the form of phosphate for growth. The amount of phosphate present in the pond waters may regulate the growth rate of phytoplanktons according to seasons (Dillon and Rigler, 1974). The phosphorus is mainly related to plankton activity in the water and decomposition on the bottom of the pond. In the present study, a significant difference in phosphorus was observed between all the six treatments. From the results of this study, it was evident that poultry manure at 6,000 kg ha^{-1} $year^{-1}$ was better than vermicompost at 15,000 kg ha^{-1} $year^{-1}$, vermicompost at 10,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$ and pig manure at 4,000 kg ha^{-1} $year^{-1}$ in increasing the amount of phosphorous in the pond waters. Dhawan and Toor (1989) however, found that vermicompost contained all the major nutrient compounds and high plankton growth occurred in ponds treated with organic manure mainly due to the content of phosphate.

The growth of fish is strongly correlated with increase in the phytoplankton and zooplankton density as a result of water fertilization. In aquaculture system, the use of organic and inorganic fertilizers provides basic nutrients and elements in ready to uptake form which are required for the production of phytoplanktons; the latter serve as a major source of food for the zooplanktons and ultimately also for the fish (Javed *et al.*, 1990). In the present study, vermicompost at 10,000 kg ha^{-1} $year^{-1}$ was found to be the best among the six treatments producing maximal number of phytoplanktons and zooplanktons followed by vermicompost at 15,000 kg ha^{-1} $year^{-1}$, cow dung at 10,000 kg ha^{-1} $year^{-1}$, poultry manure at 6,000, pig manure at 4,000 kg ha^{-1} $year^{-1}$ and the control. Chakrabarty *et al.* (2008, 2009) reported significantly higher plankton production in vermicompost treated ponds that ultimately enhanced the fish growth as compared to the traditional use of organic manure and inorganic fertilizers.

Agriculture and livestock go hand in hand wherein, livestock waste is the most commonly used organic manure in agriculture and aquaculture. Hence, the integration of vermicomposting of livestock and agricultural wastes with the aquaculture holds ample scope for developing economically and ecologically sustainable farming system for the socio-economic upliftment of rural population in developing countries (Kumar *et al.*, 2007). So far, information regarding efficacy of vermicompost as manure in aquaculture ponds is scanty. Deolalikar and Mitra (2004) have reported comparable efficacy of vermicompost with other commercial manures used in aquaculture. Vermicompost has also been reported to result in higher survival and growth of aquatic organisms including fish and prawn (Kumar *et al.*, 2007; Godara *et al.*, 2015a) without adversely affecting the water hygiene (Godara *et al.*, 2015b).

From the foregoing paragraphs, it is evident that vermicompost at 10,000 kg ha^{-1} $year^{-1}$ was a better treatment than other five treatments for majority of the water quality parameters in keeping these at maximal values in the favorable ranges. This was especially true in case of DO, alkalinity, hardness, light penetration, free carbon dioxide, phytoplanktons and zooplanktons. For other parameters too, this treatment kept their values in the favorable ranges. On the basis of all permutations and combinations, therefore, vermicompost at 10,000 kg ha^{-1} $year^{-1}$ seemed to be the best among the six treatments used in this study.

CONCLUSION

Fish can play a vital role in providing nutritional diet to the masses. This is especially true when one thinks about the growing population of the globe. To enhance the fish production by using cheap and easily available resources, like organic manures as pond fertilizers, utilization of some alternate means of pond fertilization is highly desirable; vermicompost is one such alternative. The usefulness of vermicompost in agriculture is already known. However, its potential in aquaculture as organic manure for augmentation of fish production has not been utilized. In this study, vermicompost at 10,000 kg ha^{-1} $year^{-1}$ seemed to be the best among the six treatments used. Under this treatment, all the hydrobiological parameters were in the favorable ranges and it ensured maximal fish growth too. Therefore, vermicompost at 10,000 kg ha^{-1} $year^{-1}$ is recommended as a safe manure for pond fertilization in the split doses as stipulated in this study.

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REFERENCES

APHA., 1998. Standard Methods for the Examination of Water and Waste Water. 19th Edn., American Public Health Association, Washington, DC., USA., pp: 1360-1371.

Bhakta, J.N., D. Sarkar, S. Jana and B.B. Jana, 2004. Optimizing fertilizer dose for rearing stage production of carps under polyculture. Aquaculture, 239: 125-139.

Bhatnagar, A. and P. Devi, 2013. Water quality guidelines for the management of pond fish culture. Int. J. Environ. Sci., 3: 1980-2009.

Bhusan, C. and B. Yadav, 2003. Vermiculture for sustainable agriculture. Indian Farming Digest, March 2003, pp: 11-13.

Boyd, C.E., 1990. Water Quality in Ponds for Aquaculture. 1st Edn., Auburn University Agricultural Experimentation Station, Auburn, AL., Pages: 482.

Chakrabarty, D., M.K. Das and S.K. Das, 2008. Growth performance of *Cyprinus carpio* L. in intensively different organic manures. Int. J. Environ. Res., 2: 419-424.

Chakrabarty, D., S.K. Das and M.K. Das, 2009. Relative efficiency of vermicompost as direct application manure in pisciculture. Paddy Water Environ., 7: 27-32.

Conte, F.S., 2000. Pond fertilization: Initiating an algal bloom. Technical Bulletin No. 104, Western Regional Aquaculture Centre, Alaska, pp: 1-9.

Deolalikar, A.V. and A. Mitra, 2004. Effect of vermicompost on growth of fish *Labeo rohita* (Hamilton). J. Aquacult. Trop., 19: 63-79.

Dhawan, A. and H.S. Toor, 1989. Impact of organic manures or supplementary diet on plankton production and growth and fecundity of an Indian major carp, *Cirrhina mrigala* (Ham.), in fish ponds. Biol. Wastes, 29: 289-297.

Diana, J.S. and C.K. Lin, 1998. The effects of fertilization and water management on growth and production of Nile tilapia in deep ponds during the dry season. J. World Aquacult. Soc., 29: 405-413.

Dillon, P.J. and F.H. Rigler, 1974. A test of a simple nutrient budget model predicting the phosphorus concentration in lake water. J. Res. Board Can., 31: 1771-1778.

Emerson, K., R.C. Russo, R.E. Lund and R.B. Thurston, 1975. Aqueous ammonia equilibrium calculations: Effect of pH and temperature. J. Fish. Res. Board Can., 32: 2379-2383.

Garg, S.K. and A. Bhatnagar, 2000. Effect of fertilization frequency on pond productivity and fish biomass in still water ponds stocked with *Cirrhinus mrigala* (Ham.). Aquacult. Res., 31: 409-414.

Godara, S., R.C. Sihag and R.K. Gupta, 2015a. Effect of pond fertilization with vermicompost and some other manures on the growth performance of Indian major carps. J. Fish. Aqua. Sci., 10: 199-211.

Godara, S., R.C. Sihag and R.K. Gupta, 2015b. Effect of pond fertilization with vermicompost and some other manures on the pathogenic bacterial populations of treated waters. Res. J. Microbiol., 10: 230-245.

Hassan, M., M. Javed and G. Mahmood, 2000a. Response of different levels of nitrogen from broiler droppings towards planktonic biota of major carps rearing ponds. Pak. J. Biol. Sci., 3: 1712-1715.

Hassan, M., M. Javed and G. Mahmood, 2000b. Response of different levels of nitrogen from broiler manure fertilization of ponds. Pak. J. Livestock Poult., 2: 65-71.

Javed, M., M.B. Sial and K. Javed, 1990. Effect of artificial feed on the growth performance of major carps. Pak. J. Agric. Sci., 30: 167-172.

Jhingran, V.G., 1982. Fish and Fisheries of India. 2nd Edn., Hindustan Publishing Corporation, New Delhi, India, pp: 666.

Kaur, V.I. and M.D. Ansal, 2010. Efficacy of vermicompost as fish pond manure-effect on water quality and growth of *Cyprinus carpio* (Linn.). Bioresour. Technol., 101: 6215-6218.

Kumar, P., V. Sagar, A.K. Choudhary and N. Kumar, 2007. Vermiculture: Boon for fish farmers. Fish Chimes, 27: 40-42.

Liebig, J., 1840. Organic Chemistry in its Application to Agriculture and Physiology. J. Owen, Columbus, pp: 1803-1873.

Liti, D.M., R.M. Mugo, J.M. Munguti and H. Waidbacher, 2006. Growth and economic performance of Nile tilapia (*Oreochromis niloticus* L.) fed on three brans (maize, wheat and rice) in fertilized ponds. J. Aquac. Nutr., 12: 239-245.

Mandal, B.K., 1976. Studies on the primary productivity and physico-chemical factors of fish ponds at Burdwom, west Bengal (India). Archiv Hydrobiologie, 18: 175-182.

Nath, S.S. and J.E. Lannan, 1992. Dry matter-nutrient relationships in manures and factors affecting nutrient availability from poultry manures. Tenth Annual Admin Report, 1991-1992, Office of International Research and Diversity, Corvallis, Oregon, pp: 110-119.

Osborne, J.A. and R.D. Riddle, 1999. Feeding and growth rates for triploid grass carp as influenced by size and water temperature. J. Freshwater Ecol., 14: 41-45.

Rafigue, R.M., N. Hussain and S. Mahboob, 2003. Limnological variations in River Jhelum at Dulahi Muzaffarabad. J. Nat. Sci., 1: 107-112.

Ram, N.M., O. Zur and Y. Avnimelech, 1982. Microbial changes occurring at the sediment-water interface in an intensively stocked and fed fish pond. Aquaculture, 27: 63-72.

Reinecke, A.J. and J.N. Alberts, 1987. The chemical and amino acid composition of the compost worm *Eisenia foetida* (Oligochaeta) as potential source of protein for animal feed. Suid Afrikaanse Tydskrif Natuurwetenskap Tegnologie, 6: 1-14.

Saini, V.K., R.C. Sihag, R.C. Sharma, S.K. Gahlawat and R.K. Gupta, 2008a. Biodegradation of water hyacinth, sugarcane bagasse and rice husk through vermicomposting. Int. J. Environ. Waste Manage., 2: 601-609.

Saini, V.K., R.C. Sihag, R.C. Sharma, S.K. Gahlawat and R.K. Gupta, 2008b. Relative efficacy of two methods of vermicomposting for bio-degradation of organic wastes. Int. J. Environ. Waste Manage., 2: 102-110.

Saini, V.K., R.C. Sihag, R.C. Sharma and S.K. Gahlawat, 2010. Relative efficacy of two species of earthworms in biodegradation of organic wastes under semi-arid subtropical conditions of North-West India. World Rev. Sci. Technol. Sustainable Dev., 7: 259-270.

Shelford, V.E., 1913. Animal Communities in Temperate America. Geographic Society of Chicago, Chicago, Pages: 362.

Shevgoor, L., C.F. Knud-Hansen and P. Edwards, 1994. An assessment of the role of buffalo manure for pond culture of tilapia. III. Limiting factors. Aquaculture, 126: 107-118.

Shinde, P.H., R.B. Nazirkar, S.K. Kdam and V.M. Khaire, 1992. Evaluation of vermicompost. Proceedings of the National Seminar on Organic Farming, September 28-29, 1992, Indore MP., India, pp: 54-55.

Singh, sP., C. Jee, B.N. Pandey and B.K. Singh, 2000. Study of Variation Range of Different Physico-Chemical Parameters in Relation to Fish Productivity and Health. In: Advances in Zoology, Environmental Degradation and Biodiversity, Pandey, B.N. and B.K. Singh (Eds.). Daya Publishing House, New Delhi, India, pp: 213-217.

Snedecor, G.W. and W.C. Cochran, 1989. Statistical Method. 8th Edn., Iowa State University Press, Ames, IA., USA.

Sulochana, M.S., R.R. Saxana and S.R. Gaur, 2009. Fish ponds fertilized with different organic manures: Hydro-biological characteristics. Fish. Chimes, 28: 36-39.

Trussel, R.P., 1972. The percent un-ionized ammonia in aqueous ammonia solutions at different pH levels and temperatures. J. Fish. Res. Board Can., 29: 1505-1507.

Wahab, M.A., M.E. Azim, M.H. Ali, M.C.M. Beveridge and S. Khan, 1999. The potential of periphyton-based culture of the native major carp, calbaush, *Labeo calbasu* (Hamilton). Aquacult. Res., 30: 409-419.

Wohlfarth, G.W. and G.L. Schroeder, 1979. Use of manure in fish farming-a review. Agric. Wastes, 1: 279-299.

Wurts, W.A., 2004. Organic fertilization in culture ponds. World Aquacult., 35: 64-65.