Bangladesh J. Fish. Res., 6(2), 2002: 125-134

Effects of iso-nitrogenous and iso-phosphorus fertilizers as nutrient sources on carp polyculture in Bangladesh

M. Begum*, M.A. Wahab, M.M. Ali and M.S. Haq
Department of Fisheries Management
Bangladesh Agricultural University, Mymensingh 2202, Bangladesh
*Corresponding author & present address: Bangladesh Fisheries Research Institute, Mymensingh 2201

Abstract
A 120 day long experiment was conducted to find out the effects of cow manure with urea and triple super phosphate (CUT), poultry manure with urea and triple super phosphate (PUT) and cow manure with poultry manure (CP) having similar quantities of nitrogen and phosphorus on pond productivity and fish yield. The stocking fish were rohu (*Labeo rohita*), catla (*Catla catla*) and mrigal (*Cirrhinus mrigala*) in each treatment pond at the rate of 10000/ha. All ponds were fertilized fortnightly at the rate of 4000 kg/ha cow manure with 62 kg/ha urea and 65 kg/ha TSP, 2700 kg/ha poultry manure with 62 kg/ha urea and 16 kg/ha TSP, and 4000kg/ha cow manure with 2700 kg/ha poultry manure for the treatment CUT, PUT and CP respectively. Each treatment contained an iso-nitrogen and iso-phosphorus of 56 kg and 46 kg respectively. Though the physico-chemical parameters were more or less similar in all ponds, the chlorophyll-*a* content and abundance of total plankton were significantly higher ($P < 0.05$) in the ponds receiving the fertilizer treatment of PUT than those of other treatments. Final growth as well as per unit production of fish of treatment PUT (1773 kg/ha) was significantly higher ($P < 0.05$) than that of treatment CP (1528 kg/ha) followed by that of treatment CUT (1336 kg/ha). The over all results showed that poultry manure with urea and triple super phosphate proved to be superior to cow manure with urea and triple super phosphate, and poultry manure with cow manure, even when nitrogen and phosphorus content was similar, in carp polyculture system under prevailing conditions.
Key words: Iso-nitrogenous, Iso- phosphorus fertilizer, Polyculture

Introduction

Pond fertilization enhances the growth of primary producers, which are consumed by fish, ultimately augmenting the fish crop. Locally available organic manures as well as the combined treatments of organic and inorganic fertilizers for plankton production and carp culture are of great value. The application of inorganic fertilizer with manure that contains a wide N: P ratio is beneficial because the nitrogen from the chemical fertilizer stimulates microbial degradation of the manure. Thus, phosphorus and other nutrients in the manure are released more rapidly to the water and the rate of accumulation of organic residue in the pond bottom is reduced (Chakrabarty *et al.* 1976). The addition of nitrogen and phosphorus to fish ponds stimulates pond productivity through autotrophic and heterotrophic pathways (Green *et al.* 1989). Nitrogen and phosphorus applied to ponds are assimilated directly by phytoplankton, increasing primary productivity (Boyd 1976). Animal manures, besides containing nitrogen and phosphorus, stimulate heterotrophic production, thus increasing production in ponds (Schroeder 1978 and 1980, Wolhfarth and Schroeder 1979).

Although a number of studies have been conducted on the effects of organic and inorganic fertilizers in carp polyculture (Wahab *et al.* 1994, Ahmed *et al.* 1997, Wahide *et al.* 1997), studies on the evaluation of the effectiveness of one nutrient source versus another is difficult, standardization of the rates of nitrogen and phosphorus additions permits such evaluations. Thus, the present study was undertaken to determine the effect of three iso-nitrogenous and iso-phosphorus fertilizers *viz*, cow manure with urea and triple super phosphate, poultry manure with urea and triple super phosphate and cow manure with poultry manure on water quality, pond productivity and fish production.

Materials and methods

Experimental design

Nine earthen ponds with an area of 100 m^2 each and average maximum depth of 1 m were used for this study. Ponds were normally rain fed but also there is groundwater supply and well exposed to sunlight. The experimental ponds were randomly divided into three treatment groups for three levels of iso-nitrogenous and iso- phosphorus fertilizers, *viz.*, cow manure with urea and triple super phosphate (CUT), poultry manure with urea and triple super phosphate (PUT), cow manure with poultry manure (CP). Each treatments were run with three replications. The rate of nitrogen and phosphorus was fixed to the standard inorganic fertilization rate of 125 kg urea/ha and100 kg triple super phosphate/ha which are 56 kg nitrogen and 46 kg phosphorus, respectively in Bangladesh aquaculture conditions (Table 1). The loading rates of cow-manure 4000 kg/ha with urea 62 kg/ha and triple super phosphate 65 kg/ha (CUT), poultry-manure 2700 kg/ha with urea 62 kg/ha and triple super phosphate16 kg/ha (PUT), and cow manure 4000 kg/ha with poultry manure 2700 kg/ha (CP) were calculated equivalent to 56 kg nitrogen and 46 kg phosphorus. During the course of experiment, cow manure and chicken manure samples were analyzed for total Kjeldahl nitrogen (Clesceri *et al.* 1992), total phosphorus using percholric acid digestion (Yoshida *et al.* 1976), and percent dry weight by drying at 60° C for 12h.

Table 1. Chemical composition of poultry and cow manure used in the experiment

Chemical component (% dry matter)	Cow manure	Poultry manure
Moisture	68.70	62.80
Organic matter	24.16	18.60
Total nitrogen	0.70	1.04
Total phosphorus	0.40	1.11
Total potassium	0.32	0.72

Pond preparation, stocking and fertilization

Before starting the experiment, ponds were drained out, renovated and made free of any unwanted aquatic organism. Lime (Cao) was applied at the rate of 250kg/ha and left over five days to sundry. After five days of liming, the ponds were filled up with under ground water and fertilized with respective fertilizer as selective dosages (mentioned above).

After few days of water filling and fertilization, the ponds were stocked with rohu (*Labeo rohita*), catla (*Catla catla*) and mrigal (*Cirrhinus mrigala*) at the rate of 10000 fingerlings/ha (Table 5). During the entire period of experiment, fertilizers were applied twice in a month, while both cow manure and poultry manure were applied into the ponds as slurry on wet basis where inorganic fertilizer was first diluted with water and then sprayed over the pond water.

Monitoring of water quality

Physico-chemical parameters, *viz.*, temperature, transparency, pH, dissolved oxygen (DO), total alkalinity, nitrogen (NH_4-N, NO_2-N, NO_3-N), ortho-phosphate (PO_4-P) of pond water, and chlorophyll-*a* of phytoplankton of pond monitored at an interval of every ten days between 9.00-10.00 am during the experiment. Temperature was measured by centigrade thermometer and DO by a digital DO meter and pH by a digital pH meter. Total alkalinity (mg/l) was determined titrimetrically in the laboratory according to the standard methods (Clesceri *et al.* 1992). Analyses of NH_4-N, NO_2-N, NO_3-N were done by Hach Kit (model DR-2000). Phosphate-phosphorus concentrations were determined by spectrophotometer (Milton Roy Specctronic, model 1001 plus) according to the methods of Stirling (1985). Chlorophyll-*a* (μg/L) of phytoplankton of pond was determined spectrophotometrically (Clesceri *et al.* 1992).

Bottom soil quality parameter

Chemical parameters of pond bottom soil was monitored before pond preparation and after harvesting. The samples were collected from the soil-water interface with the help of an Ekman dredge (area 225m^2). Triplicate soil samples were collected from each pond before pond preparation and after harvesting. Soil pH was determined according to the method described by Black (1965) with the help of an electric pH meter using soil:water suspension mixture (1:25). Available phosphorus was analyzed colorimetrically by 0.5m $NaHCO_3$ extraction and ascorbic and reduction method (Matt 1970). Total nitrogen was determined according to Macro Kjeldal Method (Black 1965). Organic matter was determined according to Walkley – Black Method (Black 1965).

Plankton enumeration

Quantitative and qualitative samples of phytoplankton and zooplankton were taken fortnightly throughout the experimental period. For plankton enumeration, ten litres of water samples were collected from different areas and depth of the ponds and passed through a plankton net (mesh size 25 μm) to get a 50 ml filtered sample. The samples were then preserved immediately with 5% buffered formalin (4.0g NaH_2PO_4, H_2O, 6.5g

Na_2 HPO_4 mixed with 5ml formalin and made the volume 100ml with distilled water) in a sealed plastic bottle. Plankton was counted using a Sedgewick-Rafter counting cell (S-R cell). One ml sub-sample was transferred to the counting chamber of the S-R cell (providing 1000 fields) and all cells or colony forming units occurring in 10 randomly chosen fields were counted using a compound binocular microscope (Swift M- 4000). Plankton density was estimated using the following formula:

$$N = (P \times C \times 100) / L$$

Where N = number of plankton cells or units per litre of pond water, P = total number of plankton counted in 10 fields, C = volume of final concentrate of the sample (ml), L = volume of the pond water sample (litre). Identification of plankton up to genera level was performed using keys from Ward and Whipple (1959), Prescott (1962), Belcher and Swale (1976), Palmer (1980) and Bellinger (1992).

Fish sampling and harvesting

Fish of each species from each pond were caught fortnightly using a cast net. To determine growth, total length (cm) and weight (g) of each fish were measured using a centimeter scale and electronic balance respectively. At the end of the experiment, the pond water was pumped out and all the fishes were harvested, weighed and measured. Weight gain per fish was calculated by deducting the average initial weight from the average final weight. Specific Growth Rate (SGR) was estimated as:

$$\text{SGR (\%)/ day} = [\text{Log}_e \text{ (final weight)} - \text{Log}_e \text{ (initial weight)} \times 100] / \text{culture period (days)}.$$

Data analysis

Data were analysed using statistical package, Statgraphics Version 7 and Mstat. ANOVA was performed following Sokal and Rohlf (1991) to find out whether treatments have any significant difference on growth followed Duncan's New Multiple Range Test (DNMRT) to identify whether any significant difference among the treatment means.

Results and discussion

The mean values of water quality parameters monitored during the period of experiment are given in Table 2. The values of water temperature, transparency, DO, pH, total alkalinity, PO_4-P, NO_2-N, NO_3-N, NH_4-N and chlorophyll-*a* ranged from 24.50 to 32.50°C, 14.20 to 48.20 cm, 4.5 to 6.9 mg/l, 6.50 to 9.62, 72.00 to 135.40mg/l, 0.11 to 2.80 mg/l, 001 to.042 mg/l, 0.70 to 2.7 mg/l, 0.01 to 0.90 mg/l and 30.94 to 575.96 μg/l, respectively.

Table 2. Mean values (± SD) of water quality parameters in different treatments

Water quality parameters	Treatments		
	Cow manure with Urea and TSP	Poultry manure with Urea and TSP	Cow manure with poultry manure
Water temperature (°C)	29.76 ± 0.36	29.87 ± 0.36	29.73 ± 0.36
Transparency (cm)	25.87 ± 1.37 ^{b}	31.94 ± 0.93 ^{a}	30.20 ± 1.69 ^{a}
Dissolved oxygen (mg/l)	6.18 ± 0.11	5.91 ± 0.12	6.10 ± 0.15
pH	7.67 ± 0.10	7.57 ± 0.11	7.52 ± 0.07
Total alkalinity (mg/l)	95.42 ± 2.97	95.96 ± 4.05	100.67 ± 2.78
PO_4-P (mg/l)	1.68 ± 0.15^{a}	1.69 ± 0.15^{a}	1.16 ± 0.12^{b}
NO_2-N (mg/l)	0.008 ± 0.002	0.012 ± 0.006	0.004 ± 0.00
NO_3-N (mg/l)	1.47 ± 0.07	1.48 ± 0.08	1.47 ± 0.11
NH_4-N (mg/l)	0.37 ± 0.05	0.28 ± 0.05	0.32 ± 0.05
Chlorophyll *a* (μg/l)	97.63 ± 16.29 ^{a}	198.14 ±31.43 ^{b}	213.16 ± 25.91^{b}

*Values in the same row having same superscript are not significantly different at 5% level of probability

Variations in water temperature, DO, pH, total alkalinity, PO_4-P, NO_2-N and NH_4-N among three treatment ponds were found similar. However, significant differences ($P<0.05$) in transparency, phosphate-phosphorus and chlorophyll *a* values were observed among the treatment means (Table 2). The water quality parameters measured in different treatments throughout the experimental period were found to be within the acceptable ranges for fish culture (Dewan *et al.* 1991, Ahmed 1993, Wahid *et al.* 1997, Kohinoor *et al.* 1998)

Though the nitrogen and phosphorus nutrient content in ponds were similar, it is interesting to note that phosphorus content was significantly higher ($P<0.05$) in the pond water received PUT (1.69± 0.15mg/l) and CUT (1.68± 0.15 mg/l) compared to CP (1.16± 0.12mg/l) (Table 2). The lowest level of phosphorus in the pond received CP might be due to utilization by primary producers efficiently. This is being supported by the significantly higher ($P<0.05$) amount of chlorophyll *a* content of 213.16± 25.91μg/l in the pond received CP followed by that of 198.14± 31.43μg/l (Table 2) in ponds received PUT. It has further been observed that the chlorophyll-*a* content had an inverse relationship with the phosphorus concentration. The inverse relationship between phosphorus and chlorophyll *a* concentration was also evident in the fertilized ponds (Metzger and Boyd 1980).

Differences between initial and final pH of soil in all treatments were not significant (P>0.05) (Table 3). The pH of the pond soil was not altered by application of lime. The final concentrations of organic matter in treatment ponds were higher than the initial values (Table 3). There were no significant differences in initial and final total nitrogen of soil in any treatment. Mean final soil phosphorus levels ranged from 9.58-10.60 ppm (after harvest) in fertilized ponds were lowered than initial values (10.15-12.6 ppm) (Table 3). Decreases of soil phosphorus were associated with the changes in pH. Burnt lime raised the soil pH from moderately acidic to slightly alkaline levels. At high pH, nutrients like phosphorus adsorbed on ferric hydroxide were easily released in the more alkaline upper water (Matida 1967).

Plankton population indicates the productive status of a water body, because these are the direct and basis source of food for most of the animals in aquatic habitat. The abundance of plankton with their different groups are shown in Table 4.

Table 4. Mean (± SE) abundance of phytoplankton (X 10^3 cell/l) and zooplankton (X 10^3 cell/l) in pond water under three treatments

Plankton groups	CUT	PUT	CP
Phytoplankton			
Bacillariophyceae	5.25 ± 0.69^b	10.83 ± 1.32^a	9.04 ± 1.06^a
Chlorophyceae	23.33 ± 3.19^b	36.21 ± 2.88^a	31.54 ± 3.23^{ab}
Cyanophyceae	10.92 ± 1.23^b	19.75 ± 2.06^a	18.92 ± 1.60^a
Euglenophyceae	5.25 ± 0.94^b	10.46 ± 1.16^a	10.08 ± 1.06^a
Total phytoplankton	44.67 ± 5.04^b	67.67 ± 6.48^a	71.46 ± 6.80^a
Zooplankton			
Crustacea	28.21 ± 2.76^a	30.58 ± 2.81^a	28.58 ± 2.45^a
Rotifera	14.08 ± 1.67^b	30.00 ± 3.95^a	23.75 ± 2.65^a
Total zooplankton	45.54 ± 3.60^a	52.58 ± 3.81^a	48.92 ± 4.47^a
Total plankton	80.21 ± 8.22^b	126.25 ± 8.56^a	112.38 ± 10.76^a

* Same superscript indicates non-significant difference at 5% level of probability

Phytoplankton population was mainly composed of Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae. Chlorophyceae showed the quantitative dominance over the groups and Euglenophyceae was least abundant phytoplankton in all the treatments. Zooplankton population consisted of only two plankton groups *viz.*, Crustaceans and Rotifers. The mean abundance of total phytoplankton (71.46x10^3 cell/l) of treatment CP was significantly higher (P< 0.05) than the same of PUT (67.67x10^3 cell/l) and CUT (44.67x10^3 cell/l). However, though the abundance of total zooplankton in all the treatment ponds was almost similar (P<0.05), the total plankton of ponds fertilized with PUT was significantly higher (126.25x10^3 cell/l) than that of other ponds fertilized with CP and then CUT (Table 4). Dhawan and Toor (1989) reported a higher total phytoplankton and zooplankton concentration in ponds treated with poultry droppings alone and in combination with cowdung, mainly

Table 5. Details of growth and production of fish under different test treatments of iso-nitrogenous and iso-phosphorus fertilizers in a 120 day culture period.

Treatment	Fish species	At stocking		At harvest				Production (kg/ha/4 months)	
		Average individual weight (g)	No. of fish	Average individual weight (g)	No. of fish	Survival (%)	Total weight (kg)	Species wise	Total
CUT (cow manure + urea+triple super phosphate)	Rohu	6.84 ± 1.54	33	138.85 ± 9.70	30	90.91	3.96	396	1,336±12.85[c]
	Catla	12.60 ± 1.94	33	180.80 ± 6.49	30	90.91	5.05	505	
	Mrigal	10.55 ± 0.88	34	146.50 ± 9.83	32	94.12	4.35	435	
PUT (poultry manure urea+triple super phosphate)	Rohu	6.59 ± 1.47	33	168.70 ± 10.49	30	90.91	4.86	486	1,773±18.65[a]
	Catla	12.50 ± 1.72	33	260.65 ± 3.69	30	90.91	7.44	744	
	Mrigal	10.50± 0.96	34	180.20 ± 10.92	32	94.12	5.43	543	
CP (cow manure + poultry manure)	Rohu	6.58 ±1.62	33	142.25 ± 18.18	32	96.97	4.34	434	1,528±16.50[b]
	Catla	12.65 ± 1.71	33	212.38 ± 10.44	30	90.91	5.99	599	
	Mrigal	10.58 ± 0.94	34	165.20 ± 16.71	32	94.12	4.95	495	

due to the content of phosphates and nitrates. As the fertilizers in the present experiment had a similar content of nitrogen and phosphorus, the highest concentration of chlorophyll *a* (Table 2) and total plankton (Table 4) found in ponds fertilized with poultry manure suggests that the phosphate along with the organic carbon in manure has a significant regulatory role over the nitrate in primary production. Besides 40% of total nitrogen, the poultry manure releases 50% of its total carbon and 20% of total phosphorus through leaching and decomposition (Knud- Hansen *et al.* 1993).

The growth performance of fish in terms of initial weight, final weight, weight gain, survival rates and total production are shown in Table 5. The growth of different fish in three treatments was significantly different when increase in biomass was taken into consideration. Growth and production data were extrapolated in order to express net yields on per hectare basis over the 120 days culture period. A significantly higher ($P < 0.05$) net fish yield of 1773 kg/ha was obtained in the ponds fertilized with PUT than that of 1528 kg/ha in ponds fertilized with CP followed by 1336 kg/ha of ponds fertilized with CUT. The survival rates of different species in three treatments at harvest time were fairly high and ranged from 70% to 90%. There were regular increases in weight of fish in all the treatments; however, the weight gain was higher in ponds fertilized with PUT followed by ponds received CUT fertilizer (Fig. 1).

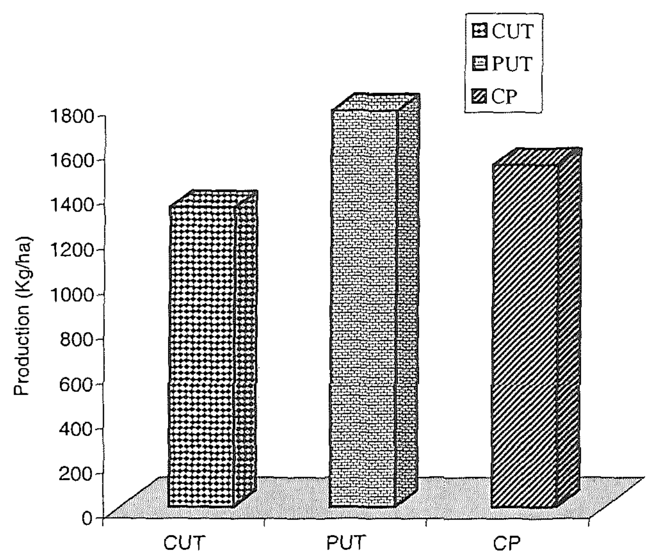

Fig. 1. Treatment wise production of fish under different treatments.

This shows the superiority of poultry manure over cow manure due to the fact that poultry manure create more favourable limits of physico-chemical factors and nutrients which in turn increase the plankton production (Sandhu 1982, Dhawan 1986). Functionally, manure might also have acted as a direct food source, but Schroeder (1978) reported that fish fed directly on manure showed poor growth and that the major contribution of the manure is to increase the population of microorganisms. Laha and Mitra (1987) evaluated the effect of poultry manure and cow dung slurry at the rate of

5,000 kg/ha and 8,000 kg/ha, respectively, on the growth of three Indian major carps, *viz.*, rohu, catla and mrigal. He observed the significant growth of fish in ponds fertilized with chicken manure than the cow dung slurry. While Mitra *et al.* (1987) evaluated the effect of poultry manure alone and in combination with pig or cow dung on the growth of catla, rohu and mrigal in four ponds. They found that the poultry manure alone or in combination with pig manure showed potentially in boosting up the productivity at comparatively low price.

Enhancement of fish yields by applying manure and fertilizers in composite fish culture ponds is an established phenomenon in many countries. However, studies on how water qualities and fish yield is related to the various iso-nitrogenous and iso-phosphorus fertilizers are very limited and there is none in Bangladesh. The present study is a part of series of experiments on the development of fertilization techniques for the composite carp culture in Bangladesh. Based on the results discussed above, it may be concluded that even the nitrogen and phosphorus content are similar in all the treatment ponds, poultry manure seems to be superior than the commonly used cow manure for better yield under the prevailing carp polyculture system.

Acknowledgements

The authors are grateful to the Agricultural Research Management Project (ARMP) IDA Credit 2815 for financial support.

Reference

Ahmed, Z.F., 1993. Electivity index and dietary overlap of *Catla catla* (Ham.) in fertilized and fed and fertilized ponds of Bangladesh. M. Sc. Thesis, Faculty of Fisheries, BAU, Mymensingh.

Ahmed, G.U., M.A.R. Hossain, M.A. Wahab and K.M.A. Rahman, 1997. Effects of fertilizer on soil and water quality parameters and growth of a carp (*Labeo rohita*) fry. *Progress. Agric.* 8(1&2): 111-114.

Black, C.A., 1965. Method of Soil Analysis, Part 2. American Soc. Agro. Madison, Wisconsin. Monograph no. 9. 1572 pp.

Belcher, H. and S. Swale, 1976. A Beginner's Guide to Freshwater Algae. Institute of Terrestrial Ecology, Natural Environmental Research Council, London.

Boyd, C.E., 1976. Nitrogen fertilizer effects on production of tilapia in ponds fertilized with phosphorus and potassium. *Aquaculture*, 7: 385-390.

Boyd, C.E., 1979. Water Quality in Warmwater Fish Ponds. Auburn University, Craftmaster Printers, Alabama.

Bellinger, E.G., 1992. A Key to Common Algae. The Institute of Water and Environmental Management, London.

Chakrabarty, R.D., D.S. Murty, P.K. Sen, A.C. Nandy and D.P Chakrabarty, 1976. Short- term rearing of Indian and exotic carps. *J. Inland Fish. Soc. India,* 8: 179-183.

Clesceri, L.S., A.E. Greenberg and R.R. Trussell, 1992. Standard methods for the examination of water and waste water. American Public Health Association. Washington, DC.

Dhawan, A., 1986. Changes in the tissuue composition and reproductive cycle in relation to feeding in major carp, *Cirrhina mrigala* (Hamilton.), PhD Thesis, Punjab Agricultural University (PAU), Ludhiana.

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 fishponds. *Biol. wastes*, 29: 289-297.

Dewan, S., M.A. Wahab, M.C.M. Beveridge, M.H. Rahman and B.K. Sarkar, 1991. Food selection, electivity and dietary overlap among planktivorous Chinese and Indian major carp fry and fingerlings grown in extensively managed rain-fed ponds in Bangladesh. *Aquacult. Fish. Managt.*, 22: 277-294.

Green, W.B., R.P. Phelps, R.P. and H.R. Alvarenga, 1989. The effects of manures and chemical fertilizers on the production of *Orechromis niloticus* in earthen ponds. *Aquaculture*, 76: 37-42.

Knud-Hansen, C.F., T.R. Batterson and C.D. Mcnabb, 1993. The role of chicken manure in the production of Nile tilapia, *Oreochromis niloticus*. *Aquaculture Fish. Managt.*, 24: 483- 493.

Kohinoor, A.H.M.., M.L. Islam, M.A. Wahab and S.H. Thilsted, 1998. Effect of mola (*Amblypharyngodon mola* Ham.) on the growth and production of carps in polyculture. *Bangladesh J. Fish. Res.*, 2(2): 119-126.

Laha, U.K. and B. Mitra., 1987. Effectiveness of some organic manures on the growth of three Indian major carps. *Sci. Cult.*, 53: 84- 86.

Matida, Y., 1967. The role of soil in pond productivity in Asia and the Far East. *FAO Fish Rep.*, 3(44): 54-63.

Matt, M.L., 1970. Colorimetric determination of phosphorus in soil and plant materials with ascorbic acid. *Soil Sci.*, 109: 220-241.

Metzger, R.J. and C.E. Boyd, 1980. Liquid ammonium polyphosphate as a pond fish fertilizer. *Tran. Am. Fish. Soc.,* 109: 563 – 570.

Mitra, B., A. Gupta and U.K Laha, 1987. Effects of some manures on the growth and production of major carps in village ponds of districts Birbhum, West Bengal, *Environ. Ecol.*, 5: 381-385.

Prescott, G.W., 1962. Algae of the Western Great Lakes Area. Wm. C. Brown Co., Inc., Dubuque, Iowa.

Palmer, C.M., 1980. Algae and Water Pollution. Castle House Publications Ltd, London.

Schroeder G.L., 1978. Autotrophic and heterotrophic production of micro-organisms in intensively-manured fish ponds and related fish yields. *Aquaculture*, 14: 303-325.

Schroeder, G.L., 1980. Fish farming in manure- loaded ponds. *In:* R.S.V. Pullin and Z.H. Shehaded (eds.) Integrated agriculture –aquaculture farming systems. International Centre for Living Aquatic Resources Management, Manila, Philippines. pp. 73-86.

Sandhu, J.S., 1982. Role of organic waste in composite fish culture. PhD thesis, Punjab Agricultural University (PAU), Ludhina.

Stirling, H.P., 1985. Chemical and Biological methods of water analysis for aquaculturists. Institute of Aquaculture, University of Stirling, Scotland. 119 pp.

Ward, H.B. and G.C. Whipple, 1959. Freshwater Biology. John Willey and Sons, Inc., New York.

Wohlfarth, G.W. and G.L. Schroeder, 1979. Use of manure in fish farming- a review. *Agricult. Wastes,* 1(4): 279-299.

Wahab, M.A., Z.F. Ahmed, M.S. Haq and M. Begum, 1994. Compatibility of silver carp in the polyculture of cyprinid fishes. *Progress. Agric.*, 5(2): 221-227.

Wahid, M.I., M.S. Haq, M.A, Wahab, Z.F. Ahmed, and M. S. Islam, 1997. Effects of fertilizer treatments on the water quality and fish production in semi-intensively managed fishponds. *Progress. Agric.*, 8 (1&2): 61-65.

Yoshida S., D.A. Forno I.H. Cook and K.A. Gomez, 1976 Laboratory Manual for Physiological Studies of Rice, 3rd edn. IRRI, Manila.

(Manuscript received 6 June 2002)