Increasing Use Efficiency of Nitrogenous Fertilisers in Fish Ponds

By Amrita Thakur, Abira Banerjee, and G.N. Chattopadhyay

High amounts of nitrogenous fertilisers are usually recommended in fish ponds to encourage the growth of primary fish food organisms, and thereby, the growth of fish. However, use efficiency of these fertilisers tends to be low under a submerged environment. Adoption of some simple management practices can improve the efficiency of nitrogenous fertilisers in fish culture operations.

The major objective of fertilising fish ponds is to improve the nutrient status of the pond soil-water environment for enhancing the growth and abundance of fish food organisms (Mandal and Chattopadhyay, 1992). Among different pond fertilising nutrients, high rates of N fertilisers are usually recommended, ranging from 200 to 400 kg/ha (Boyd et al., 2002). However, only a small portion of this added N gets transmitted to fish, while the rest is lost from the pond environment through various processes like volatilization, leaching, denitrification, etc. (Bouldin et al, 1974; Chattopadhyay and De, 1991). These processes result in significant loss of added N from fish pond systems causing substantial reduction in fertiliser N use efficiency (NUE). Major pathways for N loss from fish pond environments are shown in **Figure 1**. Schroeder (1987) found this efficiency to be as low as 18% of the total N added to the pond as manure and fertiliser. On the other hand, Gross et al. (2000), while working on channel cat fish ponds, observed about 31.5% of the added N to be ultimately transmitted to fish flesh. Their study also showed that the loss of N from the fish pond through denitrification and leaching was about 40.5%, while that from volatilization was around 12.5%. Such large-scale losses not only add to the cost of an aquaculture operation, but are also likely to affect the quality of ground water through leaching of NO_3^--N.

Mandal and Chattopadhyay (1992) suggested that maintaining higher amounts of NH_4^+-N than NO_3^--N in the pond environment may increase NUE. Since NH_4^+ ions can be adsorbed by bottom soil colloids in an easily exchangeable phase, N loss will be less and, as a result, N availability to primary fish food organisms will be improved. However, NH_4^+ ions are also subject to loss through volatilization under highly alkaline conditions—a typical situation encountered in productive fish ponds, especially during high sunshine periods. But the magnitude of this loss is quite less in a fish-pond system when compared with the loss from upland soils (Chattopadhyay, 2004). This paper discusses possibilities of using different N management practices to prevent the loss of N mainly in NO_3^- form and, thus, increase NUE in pond fish culture system.

In rice soils, use of different nitrification inhibitors is gaining popularity for increasing NUE. In view of the similarity between fish ponds and submerged rice soils (Hickling, 1971), Thakur et al. (2004) carried out a mesocosm study to assess the effects of three nitrification inhibitors, viz., neem (*Azadirachta indica*) extract, Karanj (*Pongamia glabra*) and Sodium Azide (NaN_3), on the primary productivity of water under simulated fish pond conditions. All three nitrification inhibitors were used at 1 % w/w with urea added to the submerged soil-water system at 100 kg N/ha rate and incubated under illuminated conditions. The study revealed that the use of nitrification inhibitors resulted in a substantial increase in NH_4^+/ NO_3^- ratios in soil and water, as compared to the treatment without any nitrification inhibitor (**Figure 2**). Nitrification inhibitors helped maintain larger amounts of N in readily available forms

Common abbreviations and notes: Mesocosm = simulated fish pond environment in large aquariums (term modified from "microcosm" that describes simulated fish pond environment in small glass containers); N = nitrogen; NH_4^+ = ammonium ions; NO_3^- = nitrate ions; OM = organic matter.

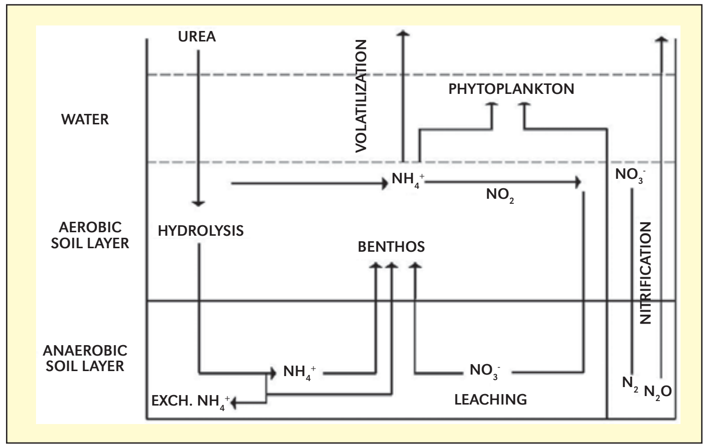

Figure 1. Major pathways for loss of nitrogen from fish pond environment.

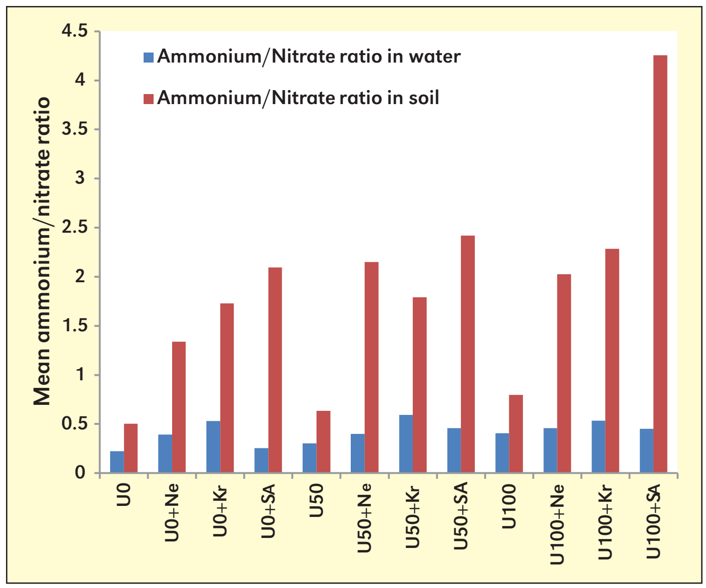

Figure 2. Mean ammonium/nitrate ratio in soil and water under different treatments with nitrification inhibitors. U_0 = no fertilisation, U_{50} = 50 mg N (supplied as urea)/kg soil, U_{100} =100 mg N (supplied as urea)/kg soil, Ne = neem (Azadirachta indica) extract, Kr = karanj (Pongamia glabra) extract, SA = Sodium azide (NaN_3).

Table 1. Effect of nitrification inhibitors on water soluble nitrogen (NH_4^++ NO_3^- mg/l).

Treatment	15	30	45	60	75	Average
	Days of Incubation					
U_0	3.47	7.77	5.20	23.8	18.2	11.7 g
U_0+Ne	6.77	8.40	9.52	28.2	24.9	15.6 ef
U_0+Kr	4.81	8.96	6.26	27.7	26.6	14.9 f
U_0+SA	5.25	9.03	7.98	26.7	23.4	14.5 f
U_{50}	4.14	9.33	8.17	25.3	21.7	13.7 f
U_{50}+Ne	8.51	10.1	11.6	38.9	32.9	20.4 bc
U_{50}+Kr	6.60	10.1	11.0	45.1	30.6	20.7 b
U_{50}+SA	7.05	13.1	8.95	34.0	30.0	18.6 cd
U_{100}	6.02	10.3	10.5	27.8	30.2	17.0 de
U_{100}+Ne	10.2	11.0	14.5	43.7	38.6	23.6 a
U_{100}+Kr	7.95	12.2	12.4	51.6	33.6	23.3 a
U_{100}+SA	8.00	14.0	13.6	37.1	32.3	21.0 b
CD (p=0.05)	1.64	2.01	2.76	13.5	5.96	

Adapted from Thakur et al. (2004). U_0 = no fertilisation, U_{50} = 50 mg N (supplied as urea)/kg soil, U_{100} = 100 mg N (supplied as urea)/kg soil, Ne= neem (Azadirachta indica) extract, Kr = karanj (Pongamia glabra) extract, SA = Sodium azide (NaN_3). Averages followed by the same letter in the column are not statistically different.

Table 2. Effect of organic matter on readily available nitrogen and gross primary productivity under simulated fish pond condition.

Treatment	Mean water soluble N (NH_4^++ NO_3^-), mg/l	Mean mineralised N (NH_4^++ NO_3^-) in soil, mg/kg	Mean gross primary productivity of water, mg C/m^3/h
N_0SA_0	10.1	101	124
N_0 SA_{100}	11.0	114	154
N_0 SA_{200}	12.4	124	176
N_{50} SA_0	16.0	139	158
N_{50} SA_{100}	16.4	150	207
N_{50} SA_{200}	17.1	164	250
N_{100} SA_0	15.4	171	182
N_{100} SA_{100}	16.8	173	264
N_{100} SA_{200}	17.6	176	301
CD (p=0.05)	1.6	6.14	46.6
SEM	0.52	2.05	15.6

N_0, N_{50}, N_{100} = N at 0, 50, and 100 mg/kg soil, respectively; SA_0, SA_{100}, and SA_{200} = 0, 100, and 200 mg organic material (starch)/g urea, respectively.

(NH_4^+ + NO_3^-) in soil and water (**Table 1**).

High amounts of organic manures are often used in the fish pond systems in Asian countries (Prowse, 1966). Generally, manures and mineral fertilisers are recommended to be used separately keeping an interval of 15 days in a month (Anon, 1985). During the period of decomposition of organic manures, the dissolved oxygen in water is used by decomposer microbes. As a result, a semi-aerobic or even anaerobic condition may develop near these decomposing organic materials. The magnitude of such development will depend on the decomposability and quantity of the organic load. It was thought that this behaviour of organic manures may be effectively utilized for improving the use efficiency of urea under fish pond conditions. Combined use of organic matter and urea is likely to develop a semi-aerobic environment around the added fertiliser, thus restricting the rapid transformation of the nutrient into NO_3^- form in the absence of adequate availability of oxygen.

Taking this hypothesis into consideration, another mesocosm study was carried out to assess the effect of using urea along with organic matter on NUE (Thakur et al., 2004). In this study, starch was used as OM and was mixed with urea at 0, 1%, and 2% (w/w). Urea, mixed with and without starch, was added to the soil-water system at 0 and 50 kg N/kg soil. Use of the starch treated urea maintained higher levels of NH_4^+-N and NO_3^--N in both soil and water phases and also helped to increase the gross primary production of water from 45 to 66% over the no OM treatment (**Table 2**). In fish culture, fertilisers are generally applied once a month. However, in view of the large-scale loss of N fertilisers from the fish ponds, it was hypothesized that split application of N fertilisers may provide a steady source of N to the primary fish food organisms. This is also expected to prevent high accumulation of N in the soil-water system at any point of time, thus helping to reduce the loss of unutilized N from the culture system. To assess the efficiency of this concept, use of 100 kg N/ha/yr was split into once-a-month, once-a-fortnight, and once-a-week treatments, keeping the total N application rate same under each of these three treatments. The study revealed that more frequent application of urea resulted in higher production of primary fish food organisms as compared to once-a-month urea application (**Figure 3**).

Since these container studies appeared to be quite effective in improving N availability to primary fish food organisms, an on-farm trial was conducted with the objective of assessing the efficiency of combined use of these N management practices under actual field conditions. For this purpose, two fish ponds of similar nature were selected at Goalpara village of Birbhum district of West Bengal, India. Both ponds were treated with similar nutrient rates, viz., N at 100 kg/ha/yr, P_2O_5 at 100 kg/ha/yr, and K_2O at 20 kg/ha/yr. In one pond, the fertilisers were used at once-a-month intervals as per the conventional norm of fish pond fertilisation practiced in India. In the second pond, N was mixed with neem extract at 1% w/w and cow dung slurry at 1:10 urea: slurry ratio and was applied in once-a-fortnight intervals. P_2O_5 and K_2O were applied once-a-month just like in the other pond. All other fish culture operations were carried out in similar manner in both the ponds. The beneficial effects of N management practices were reflected in primary productivity of the pond water. Improved N management practices increased gross and net production of primary fish pond organisms by 35 and 30%, respectively, over

Table 3. Effect of N management practice on some chemical and biological parameters of fish pond soil and water.

Parameters (Mean values)	Conventional fertilisation	Developed fertilisation
$NH_4^+ + NO_3^-$ nitrogen in soil, mg/kg	156	142
$NH_4^+ + NO_3^-$ nitrogen in water, mg/kg	16.9	17.5
Gross primary productivity, mg C/m³/h	543	733
Net primary productivity, mg C/m³/h	397	515

conventional practices (**Table 3**). However, the mean value of mineralized N in the soil phase was found to be marginally lower in the case of developed pond fertilisation. This may be due to the larger uptake of N by primary fish food organisms and also slower release of N into mineralised forms.

It is well established that in any natural pond system, growth and yield of fish are directly dependant on primary productivity levels of the pond (Lavrentyeva and Lavrentyev, 1996). Olah et al. (1986), while working on the productivity of fish ponds under different management practices in India, stated that, on an average, about 2% of the carbon synthesized through gross primary productivity of water is converted into fish flesh. Using this value, Mandal and Chattopadhyay (1992) suggested that for achieving a fish production of 1,000 kg/ha/yr fish pond water should have the capacity to assimilate 13.7 g C/m³/day through photosynthesis under Indian conditions. The improved N management practice in our on-farm trial resulted in additional primary production of 190 mg C/m³/h or 2.30 g C m³/day over the conventional nutrient application system. Using the value from Olah et al. (1986), this additional primary production may be considered equivalent to about 168 kg of fish production per hectare pond area. At an estimated fish price of INR 100/kg, the increased primary production is likely to fetch an additional gross income of INR 16,800.

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A view of farmers harvesting fish from a fish pond.

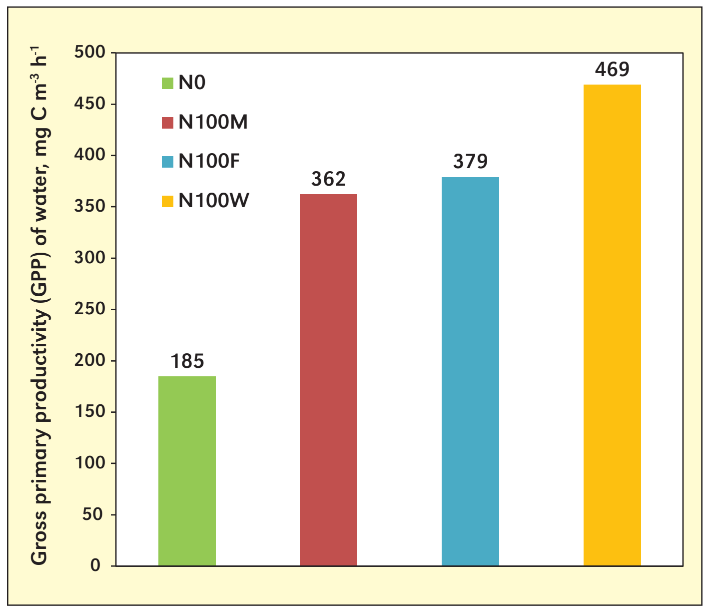

Figure 3. Gross primary productivity (GPP) of water under varying intervals of fertiliser application N0 and N100 = 0 and 100 mg/kg/yr of fertiliser N, respectively; M, F and W = once-a-month, once-a-fortnight, and once-a-week N fertiliser application, respectively.

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