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Indian carp polyculture integrated with ducks and poultry: Ecological and economic benefits

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ABSTRACT

The production and economic efficiencies of Indian carp polyculture (catla, rohu, mrigal and bata) integrated with duck farming was compared with the integration of poultry following the recommended method of stocking and management over a period of one year. About 13% enhanced fish production in the duck ponds (DP) than in poultry ponds (PP) was attributed to improved ecological conditions such as adequate dissolved oxygen (5.23 - 9.3 mg l^{-1}), relatively less amount of ammonia and total inorganic nitrogen, increased level of phosphate, higher values of primary productivity of phytoplankton (47.63–169.81 mg c m^{-3} h^{-1}) coupled with greater abundance of zooplankton (837–5322 no./50l). In general, the fish yield was inversely related with the N/P input in these ponds suggesting that increased level of nitrogen relative to phosphate was responsible for reduced fish growth in the PP, which, on the other side, was considered as P- limited. Cost benefit analysis of the data revealed that the net profit was about 60% higher in case of DP than in PP. It may be concluded that fish farming integrated with ducks or poultry would be highly effective for achieving cost effective fish production as well as for maintaining the ecosystem health.

One of the major constraints of fish culture in the developing countries is the high cost of chemical fertilizers, feed and aqua-chemicals that have made production cost of fish not only high but also caused the pond ecosystem unproductive, unhygienic and unsustainable in the long run. In contrast, fish farming integrated with poultry birds and ducks has stepped forward as a great promise to close the loop in nutrient cycle of the culture system as well as reducing the costs of traditional fish farming. The main purpose of integrated systems is, therefore, to obtain maximum benefit of fish yield and animal product through the recycling of animal excreta as pond manure which helps to maintain pond ecosystem healthier by almost uniform distribution of their droppings in the pond area, causing less pollution, aeration of water by the grazing ducks.

Fish yield obtained from integrated culture with poultry, pig, goat and cow ranged from 2859 kg/ha/yr (Geeta *et al.* 1988) to 10950 kg/ha/yr (Little and Muir 1987). Further, the fish yield obtained in ponds fertilized with animal excreta was reported to be 5–7 times higher than in normal fish pond in different locations (Nuruzzaman 1991, Uddin 1990, Soliman *et al.* 2000, Das *et al.* 2005, Shoaib 2007, Abbas *et al.* 2010). This was due to better food conversion and protein efficiency ratios compared with those of fish species reared in non-integrated ponds (Sharma and Tripathi 2003). It is stated that recycling of animal wastes may contribute more than 50% of the total input cost in fish culture (Bardach and Santerre 1979, Schroeder 1980, Edwards 1980, Dhawan and Toor 1989, Sharma 1988, Oribhabor and Ansa 2006, Bwala and Omoregie 2009).

As poultry and ducks are monogastrics, their droppings contained high amount of nutrients. Due to low carbon: nitrogen ratios, bird droppings are decomposed rapidly (Geiger and Turner 1990) favoring the production of zooplankton, benthic invertebrates, crustaceans and insect larvae (Wolhlfarth and Shroeder 1979, Ahmed and Sing 1989; Boyd and Tucker 1998, Wurts 2004, Chakraborty 2010). Mullet and catfish have been reported to grow well on diets containing 25 to 30 per cent dried poultry waste (Leray, 1970). On the other hand, the growth of carp was, however, depressed by the poultry waste in the form of pelletized diet (Kerns and Roelofs 1977). While examining the yield of carp and tilapia for 3 years, Rappaport *et al.* (1977) observed a slight decrease in fish yields due to application of chicken

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manure in the first year, but the fish yield increased by 44% over the control in the second year.

Ducks are considered as living carbon manuring machine as they loosen the pond bottom while searching for food in the shallow parts of the pond and help release of nutrients through bioturbation. Compilation of fish yield in the duck cum fish culture ponds in different locations and in different trials conducted by various investigators (Table 1) reveals that fish yield varied by a factor of about 8 ranging from 1800 kg/ha/yr in combination of Chinese carp and common carp in Hungary (Woynarovich 1980) to 14,600 kg/ha/yr in a polyculture of common carp, silver carp and grass carp integrated with duck farming in Israel (Wohlfarth 1978).

Though considerable progress has been made in China about freshwater fish production integrated with ducks and poultry, information are not adequate enough to formulate a

Table 1. A synthesis of fish yield from integrated fish culture systems used in different geographical locations under different combinations of fish species combinations.

Nature of Manure	Composition	Fish species cultured	Production (kg/ha/yr)	References
Duck dropping	N=1%, P=1.4%, K=0.62%, C=26.2%	Mullet, common carp	5670	Chen (1980)
		Indian carp, common carp	4323	Jhingran and Sharma (1980)
		Chinese carp, common carp	1800	Woynarovich, 1980
		Polyculture	10000	AIT (1986)
		Tilapia, common carp, big head carp	7665	Vincke (1988)
		Tilapia, carps	6854	Cruz and Shehadeh (1980)
		Common carp, silver carp, grass carp	14052	Barash *et al.* (1982)
		Tilapia	1784	Lovshin *et al.* (1986)
		Patin, bighead carp, Grass carp, Jelawat	6115	Geeta *et al.* (1988)
		Polyculture	14600	Wohlfarth (1978)
		Nile Tilapia		Abdelhamid et. al. (2007)
Poultry dropping	N=1.8%, P=2.3%, K=1.4%, C=15%	Prawn, fish	4500	Mohd. (1983)
		O. niloticus, Common carp, Snake heads	7300	Little and Muir (1987)
		Puntius gonionatus	5100	Djajadiredja *et. al.* (1980)
		Osteochilus hasselti, Common carp, *Helostoma temmincki, Puntius gonionatus*	10800	Djajadiredja *et. al.* (1980)
		O. aureus	5900	Burn & Stickney (1980)
		Polyculture	7300	Milstein *et al.* (1995)
Pig dropping	N=0.59%, P=0.46%, K=0.43%, C=15%	Silver carp, big head carp, common carp, grass carp	6570	Olah *et al.* (1986)
		T. andersonii	7000	Vincke (1988)
		C. gariepinus	7510	Vincke (1988)
		T. niloticus	8000	Vincke (1976)
Goat dropping	N=1% P=0.52% K=0.79% C=17%	Patin, bighead carp, grass carp, Jelawat	2859	Geeta *et al.* (1988)
		Polyculture	3600-6300	Cruz and Shehadeh (1980)
		Polyculture	5000-7000	Little and Muir (1987)
Cow	N=0.3% P=0.2% K=0.1% C=14%	Carp, Tilapia	10950	Little and Muir (1987)
		Tilapia	3000	Green *et al.* (1989)
		Polyculture	10950	Schroeder (1975)

standard practice for culture of Indian carps integrated with farming of ducks and poultry. Indian carps are most widely cultivated species of fish which are not only cultured in India, but also extensively cultured in Bangladesh, Ceylon, Burma, Pakistan, and some other Asian countries. Integrated farming of Indian carps is considered eco-friendly and cost effective.The purpose of the present study is to examine the production potentials and economic benefits of fish integrated with duck and poultry birds for a large-scale adoption for rural development.

MATERIALS AND METHODS

Lack of adequate rainfall in the area resulted in the scarcity of natural fish ponds. Due to limitations in the availability of ponds of each integrated farming system, two ponds each for duck cum fish culture (DP) and poultry cum fish culture (PP) were selected in Kalyani (University of Kalyani) as well as in Haringhata (distance of 6 km) However, there was no heterogeneity between two sites investigated. Due to the same reason of unavailability of ponds, it was not possible to include a control pond. The fish yield of the local ponds using the traditional method of fish farming was, however, used for comparison. The surface area of these ponds varied between. 05 ha and 0.1 ha respectively. The depth of the ponds was maintained at 1.75 m by periodical addition of water. Lime was applied in both ponds at the rate of 40 kg/ha.

The birds were initially given prophylactic measures against epidemics and reared in the duck (14 m^2) and poultry bird (7.5 m^2) houses constructed on the bank of each pond. The space for each duck and poultry bird available was 0.46 m^2 and 0.3 m^2 respectively. Thirty Khaki Campbell ducks (five months old) and 24 white leghorn poultry birds (six months old) were stocked for farming carp polyculture according to the recommendation of Sharma and Tripathi (2003). The same conditions were maintained in two farm sites.

All the ducks were released into the pond for 6–8 hours to fetch most of their daily feed requirements from weeds and molluscs, insects, etc. Every evening the ducks were fed with the mixture of EPIC feed (crude protein 18%, crude fibre 8%, calcium 3%, moisture 11% available phosphorus 0.5%, Vitamin A 8000 IU/kg, Vitamin D_3 1200 IU/kg and Thiamine 3 mg/kg) and rice bran (3:2) given at the rate of 100 g/bird/day or 8% of their body weight (Jhingran 1998). The droppings of 30 ducks and small amounts of uneaten food particles from the duck house summed up to around 1.9 kg/day (dry weight) which was washed directly into the duck pond daily in the morning.

Unlike ducks, all the poultry birds were confined in the poultry house and were fed thrice a day with EPIC feed and rice bran (4:1) at the rate of 15% of the total body weight, split in three doses. The birds were also vaccinated periodically to prevent bird epidemics and pandemics. The poultry birds and ducks were also occasionally fed with mollusks powder and calcium powders to avoid calcium deficiency. The poultry droppings were allowed to deposit in PP and became a source of manure.

Polyculture of catla *(Catla catla*), rohu *(Labeo rohita*), mrigal *(Cirrhinus mrigala*) and bata *(Labeo bata*) was followed in the present study. Advanced fry of catla (9), rohu (8), mrigal (7) and bata (6) were acclimatized for a week and introduced into the culture ponds at the rate of 6000 ha^{-1} using the stocking ratio of 3: 3:2:2 (Sharma and Tripathi 2003). Stocking was done during August, 2004 and harvested after 380 days of culture. No supplementary feed was given; natural plankton was the source of food for the fishes during the culture period.

Samples of surface water and bottom sediment were collected from each pond at 9.00 h every ten days. The samples were analyzed for different species of nitrogen (ammonium-N, nitrite-N and nitrate-N), phosphate and other water quality parameters (temperature, pH, free CO_2, total alkalinity and DO) following the standard methods described in APHA (1998) and Wetzel and Likens 1991). Primary productivity of phytoplankton was determined following the dark and light bottle method (Vollenweider 1974). Soil samples were analyzed for pH, organic carbon, available-N and available-P as per the methods described by Jackson (1967).

About 50–60% of the fishes were harvested from each pond every two months and the average weight of fish was recorded. Total harvest was done after the grow out period of 380 days and their total yield was estimated.

Cost-benefit analysis of fish yield was performed using the standard methods (Jolly and Clonts 1993). As the poultry pond (0.05 ha) was smaller than the duck pond (0.1 ha), the production data as well as expenditure occurred in the former were multiplied for comparison under similar unit area of the ponds. The net present value (NPV) was calculated at 15% discount factor. Internal rate of return (IRR) was used for ranking between the two programmes (duck cum fish culture and poultry cum fish culture). Ranking was given based on the relative size of the IRR with the largest IRR receiving the highest rank.

RESULTS

Survival, growth and fish yield

The survival rate of fish did not differ between the duck cum fish culture (DD) and poultry cum fish culture (PP) as more than 90% of the stocked fish were recovered at harvesting.

The growth rate of *mrigal* was about 35 to 186% higher than the remaining three species of fish cultured in both PP and DP (Table 2). The total fish yield was 13% higher in DP (2565 kg/ha) compared to PP (2268 kg/ha) attributable to increased growth rates of all the species of fish (Table 2).

Primary productivity

Both the gross (GPP) and the net primary productivity of phytoplankton (NPP) were higher in PP (50.77–176.12 mg

Table 2. Mean (±SE) of growth rate and yield of different species of Indian carps raised in duck-cum and poultry-cum fish ponds

Fish species	Duck cum Fish Culture Pond (DP)				Poultry cum Fish Culture Pond (PP)			
	1st year		2nd year		1st year		2nd year	
	Growth rate (g/day)	Yield (kg/ha)	Growth rate (g/day)	Yield (kg/ha)	Growth rate (g/day)	Yield (kg/ha)	Growth rate (g/day)	Yield (kg/ha)
Catla	1.34±0.14	810	0.55±0.35	351	1.2±0.015	729	0.61±0.07	384
Rohu	1.2±0.01	729	0.70±0.01	550.8	1.07±0.01	648	0.68±0.06	544.5
Mrigal	1.89±0.02	756	1.03±0.12	325	1.62±0.02	648	0.82±0.08	240
Bata	0.66±0.001	270	0.37±0.04	561.6	0.59±0.001	243	0.36±0.04	551.3
Punti	-	-	0.19±0.01	150.1	-	-	0.20±0.03	159.1
Prawn	-	-	0.28±0.03	188.5	-	-	0.29±0.04	180

C m^{-3} h^{-1}) than in DP (47.63–169.81 mg C m^{-3} h^{-1}). Both values tended to rise gradually showing a peak during the period of 130 to 180 days of culture in DP and 130 to 210 days of culture in PP and then declined (Fig. 1).

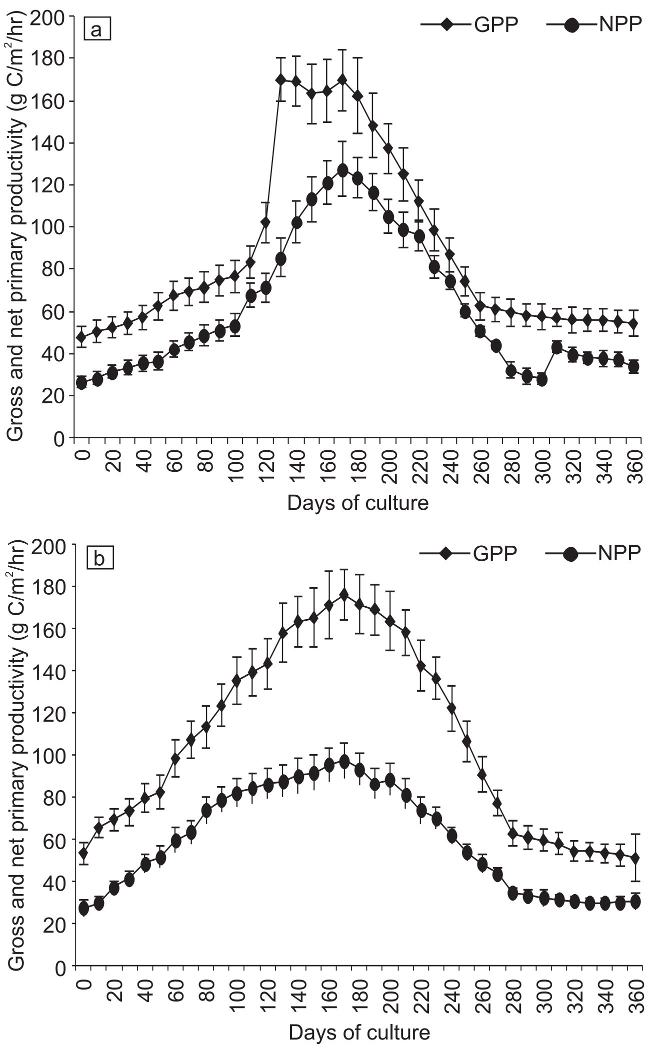

Fig. 1. Temporal variability of gross and net primary productivity of phytoplankton in the fish culture ponds integrated with duck (a) and poultry birds (b).

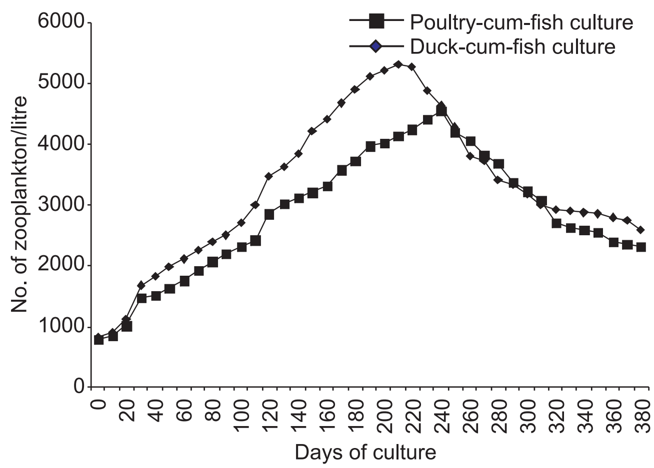

Fig. 2. Temporal variability of number of zooplankton in the fish culture ponds integrated with duck and poultry birds.

Zooplankton

The composition of zooplankton differed between DP and PP. The DP pond was dominated by cladocerans followed by rotifers and copepods, whereas, the PP pond was represented by the dominance of copepods followed by cladocerans and few rotifers.

The amount of zooplankton varied between 837–5322/l and 789–4561/l in DP and PP respectively (Fig. 2).

Water quality

There was no difference in water temperature (23°C and 30°C), pH (7.2–8.2) and free CO_2 (3.277 - 3.469 mg l^{-1}) of water between DP and PP. Total alkalinity of water ranged from 120 to 168 mg l^{-1} and 136 to 194 mg l^{-1}in PP and DP, respectively. The dissolved oxygen of water ranged from 5.2 to 9.3 mg l^{-1} in DP, and from 5.1 to 7.2 mg l^{-1} in PP (Table 3).

Nitrogen species

The temporal responses of three species of inorganic nitrogen were similar in both ponds. The concentration of total N_i observed in PP was about 64% higher than in DP due to increased levels of all the three species of nitrogen. In

Table 3. Range and mean (±SE) of water quality parameters during the culture period in two ponds

Parameters	Duck cum fish culture pond		Poultry cum fish culture pond	
	Range	Mean±SE	Range	Mean±SE
Water temp. (°C)	23.1–32	29.61±0.397	25.1–32	29.84±0.292
Water pH	7.2–8.2	-	6.9–8.1	-
Free CO_2 (mg/l)	1.91–4.82	3.22±0.12	2.44–4.93	3.469±0.124
Total alkalinity (mg/l)	120–157	134.60±1.231	147–194	159.97±1.666
Dissolved oxygen (mg/l)	5.19–9.3	6.67±0.139	5.12–7.23	6.34±0.092
Total N_i (mg/l)	0.343–0.937	0.599±0.026	0.472–1.368	0.982±0.031
PO_4-P (mg/l)	0.052–0.449	0.199±0.021	0.073–0.367	0.184±0.013
N_i/P	0.76–11.21	4.91±0.567	2.97 – 12.19	6.172±0.425

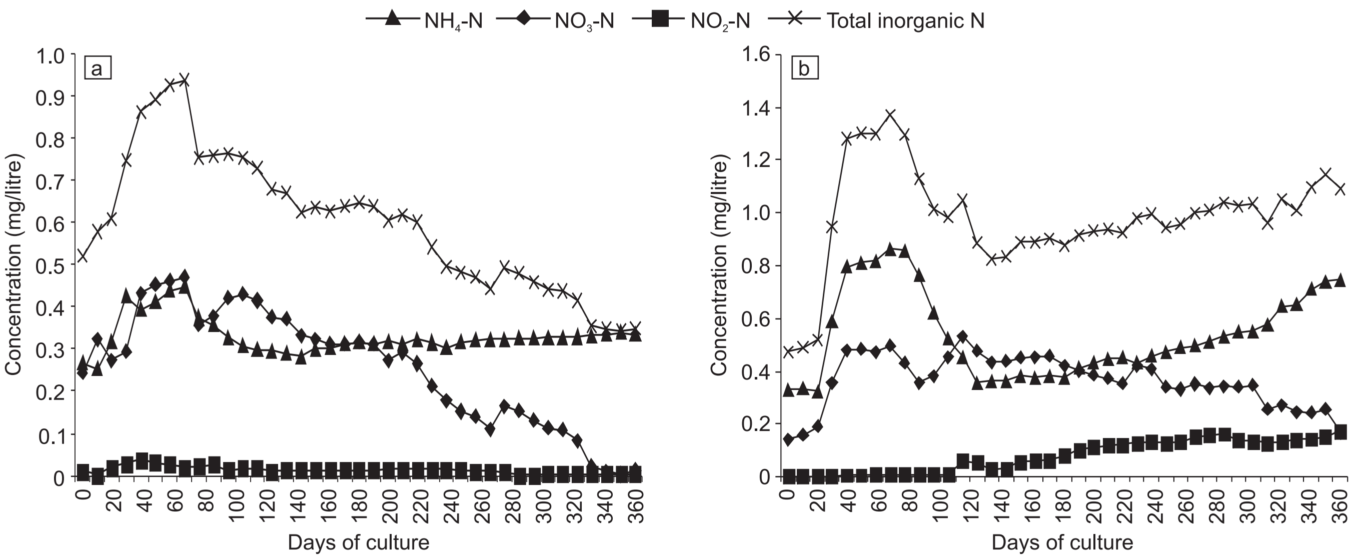

Fig. 3. Temporal variability of different species of N in the duck cum fish culture and poultry cum fish culture ponds.

general, the concentration of NH_4 was higher during the early part of culture (20 to 70 days) than during the later period of culture (130–290 days). The concentration of NO_2 remained consistently low ranging from 0.001 to 0.037 mg/l in DP and 0.001 to 0.175 mg/l in PP. Temporal variations of nitrate was almost parallel with that of NH_4 till day 190, but followed a decline in the remaining part of culture (Fig. 3).

Orthophosphate

The concentration of orthophosphate observed in DP (0.19 mg/l) was 7% higher than in PP (0.18 mg/l). The values tended to increase steadily as the culture period progressed (Table 3).

Ni/P

The N_i/P ratio of water ranged from 0.76 to 12.19 in different months of the fish growth. On average, the N_i/P ratio was about 26% higher in PP (6.17) compared to DP (4.91). The values were higher during the early part of culture than during the later period (Table 3).

Table 4. Range and mean (±SE) of soil parameters during the culture period in two ponds

Parameters	Duck cum fish culture pond		Poultry cum fish culture pond	
	Range	Mean±SE	Range	Mean±SE
Soil pH	6.3–7.9	-	5.9–7.4	-
Av-N (mg/100 g of soil)	28.0–70.3	50.27±1.985	28.7–82.9	58.62±2.718
Av-P (mg/100 g of soil)	10.64–37.02	16.728±1.309	11.5–14.88	12.907±0.139
Organic-C (mg/100 g of soil)	139.42–189.15	165.2±1.868	160.89–276.47	187.86±4.773
C/N ratio	2.1–5.6	3.49±0.165	2.1–5.7	3.39±0.153
N/P ratio	1.63–4.77	3.298±0.131	2.49–6.26	4.481±0.173

Table 5.Cost benefit analysis of fish culture in the duck-cum-fish culture and poultry cum-fish culture system

Sl.No	Items	Duck cum fish culture		Poultry cum fish culture	
		Expenditure (₹)	Revenue (₹)	Expenditure (₹)	Revenue (₹)
1.	Initial investment:				
(a)	Pond preparation	515.00		515.00	
(b)	Bird house (rental)	1000.00		1200.00	
(c)	30 pieces of duck as ₹ 50.00/pc 48 pieces of poultry as ₹ 50.00/pc	1500.00		2400.00	
(d)	600 fish fingerlings (Avg wt-7.0 g as ₹ 50/kg)	207.90		207.90	
2.	Feed 450 kg as ₹ 8.20/kg for duck and 980 kg as ₹ 7.50/kg for poultry	3688.00		7348.00	
3	Medicine as ₹ 3.00	90.00		144.00	
4	Lime 20 kg as ₹ 7.50/kg	150.00		150.00	
5	Miscellaneous	1450.00		1850.00	
	Total cost (TC)	8600.90	13.814.90		
6	Fish selling duck pond 256.5 kg and in poultry pond 226.8 kg at ₹ 45.00/kg		11542.50		10206.00
7	Egg selling of duck 28 females Avg 240 eggs/bird/ year as ₹ 2/egg and Poultry birds 48 female Avg.150 eggs/ bird/year as ₹ 1.5/egg		13440.00		10800.00
8	Bird selling, duck @ ₹ 40 and poultry @ ₹ 40/kg		1200.00		3840.00
	Total revenue (TR)		26182.50		24846.00
	Net return (TR-TC)		17581.60		11031.10
9	Net present value (NPV) at 15% (0.87) discount factor	14177.87	7801.12		
10	Benefit cost ratio (BCR)	2.648 > 1	1.565 > 1		
11	Internal rate of return (IRR)	83%	55%		

Sediment quality

In DP, the soil pH was higher (6.3–7.9) than in PP (5.9 to 7.4). The amount of available-P ranged from 0.53 to 1.85% in PP and from 0.58 to 0.74% in DP. The amount of organic carbon was 15 to 46% higher in the soil of PP compared to DP. The amount of available-N was considerably higher in PP than in DP. The range of C: N in the PP was between 2.1–5.7 and between 2.1–5.6 in the DP (Table 4).

Economics

The expenditure for integrated fish farming includes expenses for pond preparation, huts for duck and poultry birds, purchase of duck and poultry birds, fish fingerlings, bird feeds, medicines, lime, and miscellaneous items. Income is generated from the sales of bird eggs, fish and sales of poultry birds and ducks at the time project end. As the poultry birds and ducks were in egg laying stage and had the capacity to continue egg production during the next year of fish culture, the birds were not sold for meat, but their market values were used for calculating the economics (Table 5). There was no difference in the expenditures involved in pond preparation and purchase of fish fingerlings between DP and PP. The cost for duck feed was nearly twice the cost of poultry feed. The income generated from the eggs and fish from the DP was higher than from the PP, the prices of poultry birds were higher than the ducks. The resulting net return was higher in the DP (₹ 17,581.60;US $= ₹ 45.00) than in the PP (₹ 11,031.10). Using the data of IRR for one year, it is evident that duck cum fish culture pond was more profitable than the poultry cum fish culture pond.

DISCUSSION

Basically the fish yield was the function of interplay of various physico-chemical and biological factors of pond ecosystem. Carp-polyculture integrated with duck or poultry birds was found to be cost effective as it closes the loop in nutrients liberated from the droppings of birds, and induced the autotrophic and detrital food chains of fishes. As the bird droppings were the main source of nutrients in the pond, and precluded the use of allochthonous fertilizers and supplementary feed in culture ponds, the total cost of fish production was substantially reduced. The mechanism of manure action on fish production was based upon the well known ecological principle of manure recycling that prompted the production of the autotrophic and detrital food chains via zooplankton and benthic animals.

Because of a higher fish yield in the duck integrated system than in the poultry birds integration, it appears that the former had an advantage over the later system due to its dynamic and symbiotic direct system approach that closes the loop in organic manure. In general, ducks are considered as living carbon manuring machine. This resulted in a benign environment mediated through various activities of the

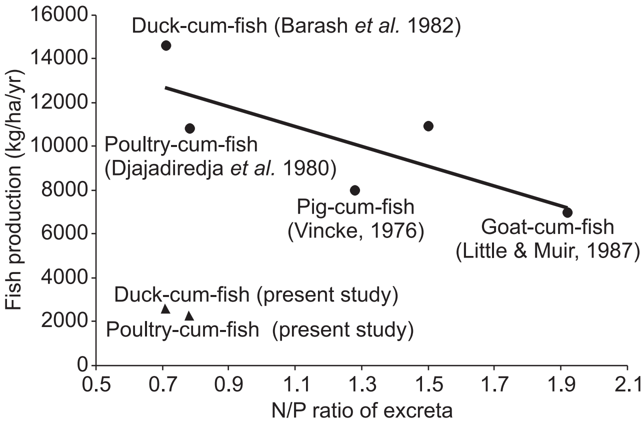

Fig. 4. General relationship between the maximum fish yield and N/P ratio of manure of different animals (duck, chicken, pig, cow, goat) integrated with fish culture in different locations.

grazing ducks, such as pond aeration by their swimming, controlling aquatic weeds and vegetation, bottom raking while searching food from pond mud. This leads to increased primary and secondary productivity in duck ponds compared to ponds receiving wastes from other animals (Wilber 1971, Kapur, 1981, Kapur and Lal 1986, Yadava and Bhatnagar 1992, Soliman *et al.* 2000).

The approximately 13% higher fish production in the DP than in PP may be attributed to better environmental conditions such as adequate dissolved oxygen, relatively less amount of ammonia and total inorganic nitrogen, increased concentration of phosphate, higher values of primary productivity of phytoplankton coupled with greater amount of zooplankton.

The fish yield in the present study was inversely related with the N/P input from the birds dropping (Fig. 4) suggesting that increased level of nitrogen relative to phosphate was responsible for retardation of fish growth in the PP. Such an inverse relationship of conversion efficiency between total N and P input from chicken manure and net fish yields was also known. Lin *et al.* (1997) reported in treatments with lower chicken manure input at 0.5 and 1 kg N/ha/d, the nitrogen gain in fish biomass was 216.7 and 116.1% of that manure input respectively. Compilation of fish yield data with the N/P input from different animal manure (Fig. 4) revealed almost similar results.

Cost benefit analysis of the data revealed that the net profit was about 60% higher in case of DP than in PP. It may be concluded that the integrated fish farming using Indian carps would be one of the low-cost solutions in the developing countries for reducing the cost of fish production as well as for maintaining the ecosystem health by avoiding the use of chemical fertilizers.

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