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Comparison between existing low input and high input integrated pond-dike aquaculture systems in some villages of Muktagacha, Mymensingh

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Abstract

An on-farm study was conducted during July 2002 to February 2003 under EC funded POND LIVE project to compare two major existing integrated pond-dike production systems in Mymensingh area of Bangladesh. Three farmers practising carp polyculture managed as low input system and other three practising pangas monoculture managed as high input system were selected from two neighbouring villages, Noshirpur and Bashati of Muktagacha Upazilla under Mymensingh district. The input-output of both categories of farming systems were computed in terms of biomass (Kg/ha), money value (Cash and non-cash Taka/ha) and nutrient (Kg Nitrogen/ha). In low input system averages of pond and dike inputs were 9,235 Kg/ha and 6,553 Kg/ha, respectively with the averages of outputs of the same were 1,526 Kg/ha and 7,788 Kg/ha, respectively. Whereas, in case of high input system the averages of pond and dike inputs were 72,818 Kg/ha and 7,135 Kg/ha, respectively with the averages outputs of the same were 32,460 Kg/ha and 6,971 Kg/ha, respectively. These pond dike inputs and outputs were converted into cash Taka as well as non-cash Taka. The averages of pond inputs in Kg N were 74 Kg N/ha in low input system and 2,025 Kg N/ha in high input system. The averages of pond outputs in Kg N in low and high input systems were 36 Kg N/ha and 690 Kg N/ha, respectively. Significant difference ($P < 0.001$) was found between pond inputs in Kg biomass and Kg N of low input system and high input system. Pond outputs in Kg biomass, cash Taka and Kg N of low and high input systems were also significantly different.

Keywords: Integrated, Pond-dike, Aquaculture

Introduction

The integration of aquaculture with agriculture has been recommended as a solution to the problems like acute cultivable land and water scarcity with environmental degradation due to increased demand for food to support an increasing population (Barg *et al.*, 2000). The incorporation of aquaculture component into agricultural farming system results in pond-dike systems that are self-sustaining, efficient and ecologically sound, producing a diverse range of products on a sustainable basis (Lightfoot *et al.*, 1996; Ruddle and Zhong, 1988). Pond-dike systems decrease the environmental hazards of food production through minimizing the use of external chemical or other expensive inputs and as a result maximizing profitability on a sustainable basis by recycling wastes or by-products among components of farming systems. Though the concept of pond-dike systems are widely used in China and throughout South and Southeast Asia, yet it has not been sufficiently researched (Korn, 1996). Pond-dike systems are complex and diversified in nature. Nutrient management may be one of the main areas that can be improved in the integrated pond-dike systems for sustainable livelihood. However, few quantitative insights on nutrient cycling through pond-dike systems exist. Considering aquaculture as the main component of farming systems, two major types of pond-dike systems are being practised in Bangladesh, such as low input system and high input system. For optimum production and sustainability of the systems a thorough research should be carried out, especially on nutrient dynamics and nutrient use efficiency what has not yet been attempted. A preliminary effort towards comparison between the input and output status of the two major pond-dike integrated systems has been attempted in this study.

Materials and Methods

Farmers & farm selection

Farmers and farms were selected randomly from two categories of farmer groups (poor and rich group both practising pond-dike farming) as identified through the Participatory Community Appraisal (PCA) conducted by EC Pond Live project under the Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh. Three poor farmers practising carp polyculture with low input management and three rich farmers practising Thai pangas monoculture with high input management were selected. Three low input ponds designated as P_1, P_2 and P_3 were of 13.54, 12.05 and 31.94 dec. in areas with dike areas of 13.25, 1.46 and 2.19 dec., respectively. Three high input ponds were of 18, 18.10 and 22.52 dec. with dike areas of 1.68, 3.6 and 3.61 dec., which were designated as P_4, P_5 and P_6, respectively.

Input-output monitoring

Four different formats were developed to collect input-output information of pond and dike. Format-1 was used for recording daily used inputs in ponds, format-2 for daily used inputs on dikes, format-3 for daily obtained outputs from ponds and format-4 for daily obtained outputs from dikes. Farmers were trained and requested to record input-output information of both ponds and dikes on daily basis and the information were collected from them on weekly basis. Initially the farmers were visited two times per week to check record keeping and once they understood the subject, the records were collected on weekly basis up to month 4, later on fortnightly basis. Each farmer was given a balance to record the weight of inputs and outputs of pond and dike. All input-output weights were taken in Kg. Prices of inputs purchased were expressed in cash Taka and the prices of inputs of own source i.e. which were not purchased, were expressed as non-cash Taka. Likewise the prices of outputs sold were expressed as cash Taka and that of outputs consumed were expressed as non-cash Taka.

Pond and dike farming

The low input farmers stocked ponds with carp species like rohu *(Labeo rohita)*, catla (*Catla catla*), silver carp *(Hypophthalmichthys molitrix)*, mrigal *(Cirrhinus cirrhosus)*, common carp *(Cyprinus carpio)*, gonia *(Labeo gonia)*, silver barb *(Barbodes gonionotus)* and tilapia *(Oreochromis niloticus)*. The major stocked species were rohu, catla, mrigal, silver carp and silver barb. The high input farmers stocked their ponds with Thai pangas *(Pangasius hypopthalmus)* and with a very small number of rohu *(Labeo rohita)*, catla *(Catla catla)* and tilapia *(Oreochromis niloticus)*, to keep plankton bloom under control. Farmers of both categories used pond dikes for vegetables and fruits production. The low input farmers cultivated mainly different types of vegetables, whereas the high input farmers produced mainly papaya as fruits and vegetables.

Analysis of water quality parameters

Water quality parameters were measured monthly and samples were collected between 9:00 and 10:00 am from 4 - 5 locations of each pond using a PVC pipe of 5 cm diameter. Samples were collected from the entire water column, mixed and collected in plastic bottles. Water temperature (^{0}C) was measured at the pond site by using a Celsius thermometer. A secchi disc of 20 cm diameter was used to measure transparency (cm). Dissolved oxygen (mg/L) was measured by titrimetric method (APHA, 1992). Digital pH meter (CRONING pH meter 445) was used to measure pH. Total alkalinity (mg/L) was determined by titrimetric method (APHA, 1992). Chlorophyll-a (μg/L) was measured by filtering 100 ml water sample through glass fiber filter paper (Whatman GF/C) with the help of vacuum pressure air pump and using a spectrophotometer (Milton Roy Spectronic, model 1001 plus). For nitrate-nitrogen (mg/L), nitrite-nitrogen (mg/L) and phosphate-phosphorus (mg/L) analysis, filtered samples were used. Unfiltered water samples were used for total nitrogen (mg/L), total ammonia nitrogen (mg/L), and total phosphorus (mg/L) analysis. HACH kit (DR-2010) was used to determine nitrate-nitrogen (NO_3-N) by cadmium reduction method, nitrite-nitrogen (NO_2-N) by diazotization method and phosphate-phosphorus (PO_4-P) by ascorbic acid method. Total ammonia nitrogen (salicylate method), total nitrogen (persulfate digestion method), total phosphorus (acid persulfate digestion method) were determined using a HACH kit (DR-4000) and respective reagents.

Conversion of input-output into nitrogen

Input-output samples were collected and nitrogen content was determined in the laboratory by micro Kjeldhal method (AOAC, 1980). For conversion of Kg input-output into Kg nitrogen, %N value was determined in the laboratory analyses and the available literature (Gopalan *et al.,* 1993) data were used.

Statistical analysis

For statistical analysis t-test was done using SPSS programme, version 10.

Results and Discussion

Water quality parameters

Table 1 shows that the mean transparency 25.40 cm of low input ponds was significantly different from the mean transparency 15.80 cm of high input ponds ($P < 0.05$). Fig. 1 shows that though the mean transparency values in two systems were in two different levels (low level in high input ponds and high level in low input ponds), their monthly fluctuation trends were more or less similar. It indicates that the fluctuations due to environmental factors were same but the levels in two systems were not the same only due to the influence of different quantities and kinds of inputs used in two systems. Kohinoor (2000) recorded transparency values ranging from 15 to 58 cm, and Diana *et al.* (1987) reported 50 cm average transparency for ponds receiving little fertilization and 25 cm or less receiving significant amount of nutrient, which agrees with the present study. Transparency below 20 cm due to plankton abundance indicates high productivity (Boyd, 1990). According to that the high input ponds may be considered as highly productive as the transparency values were always below 20 cm except in August, whereas low input ponds were comparatively less productive.

Mean temperature, total alkalinity, pH, dissolved oxygen, nitrate-nitrogen, nitrite-nitrogen, phosphate-phosphorus and total phosphorus in low input ponds were not significantly different from those of high input ponds (Table 1). The mean temperature of high input system (25.2^0 C) was a little bit higher than that of low input system ($23.97\ ^0$ C) (Table 1) and this is common in other studies (Kohinoor *et al.,* 1999).

Table 1. Water quality parameters (mean value ± S.E.) as recorded from low and high input ponds

Parameters	Low input ponds	High input ponds	Level of significance
Transparency (cm)	25.40 ± 2.04	15.8 ± 2.14	S (P<0.05)
Temperature (^{0}C)	23.97 ± 0.55	25.20 ± 0.25	NS
Total alkalinity (mg/L)	65.13 ± 13.56	114.40 ± 13.04	NS
pH	7.33 ± 0.03	7.07 ± 0.13	NS
Dissolved oxygen (mg/L)	5.83 ± 0.74	5.40 ± 0.25	NS
Total nitrogen (mg/L)	2.13 ± 0.23	5.13 ± 0. 42	S (P<0.01)
Nitrate-nitrogen (mg/L)	0.028 ± 0.00	0.20 ± 0.10	NS
Nitrite-nitrogen (mg/L)	0.003 ± 0.00	0.13 ± 0.08	NS
Total ammonia nitrogen (mg/L)	0.23 ± 0.03	1.17 ± 0.12	S (P<0.01)
Total phosphorus (mg/L)	1.10 ± 0.20	4.17± 1.22	NS
Phosphate-phosphorus (mg/L)	0.27 ± 0.08	0.83 ± 0.44	NS
Chlorophyll-a (μg/L)	100 ± 20.28	491 ± 53.96	S (P<0.01)

Total alkalinity in high input ponds (mean 114.4 mg/L) were always in higher level during the whole sampling period in comparison to low input ponds (mean 65.13 mg/L) (Table 1, Fig. 3) and the trends of two systems were more or less similar. The result of the present study complies with the inference of Boyd (1992). The use of organic inputs may keep alkalinity at higher level (Knud-Hansen *et al.*, 1991; Teichert-Coddington *et al.*, 1992; Diana *et al.*, 1994).

pH values in low input ponds were very close to those of high input ponds during most of the sampling periods except two sampling months, October and February, when the values were higher in high input ponds, might be due to sharp change of alkalinity in both the months. pH in both systems were within the range of 6.5-7.5 and were suitable for fish culture (Boyd, 1992).

Dissolved oxygen values in high input ponds (mean 5.4 mg/L) were lower or very close to those of low input ponds (mean 5.83 mg/L) (Table 1) during most of the sampling months except once in October, when the value was higher in high input ponds (Fig. 5). Due to difference in organic load in pond bottom dissolved oxygen in ponds may differ and reflected in high input ponds.

Mean values of total nitrogen, total ammonia nitrogen and chlorophyll-a in low input ponds were found to differ significantly ($P < 0.01$) from those of high input ponds (Table 1). Total nitrogen (TN) in low and high input ponds fluctuated in parallel during the entire sampling periods (Fig. 6) maintaining higher level in high input ponds than that of the low input ponds. It increased gradually up to September, then decreased steadily up to December and then started rising up to rest of the months. The mean total nitrogen was 2.13 mg/L and 5.13 mg/L in low and high input ponds, respectively. Mean values of 0.95, 1.59, 0.89, 1.67 and 2.36 mg/L TN in ponds fertilized with different regimes has been reported by Yang Yi *et al.* (2001), which are similar to the result of low input ponds under this study, but the value in high input system was higher which might be due to the use of comparatively high nitrogen contained feed (3.15 - 3.44% N).

Fig. 9 shows that total ammonia nitrogen (TAN) values in high input ponds was higher in comparison to those of the low input ponds during most of the months except in July, August and February, and then noticeable differences were observed. This might be due to difference in input used in two systems..The mean value was 0.23 mg/L in low input systcm which was 1.17 mg/L in high input system (Table 1). Yang Yi *et al.* (2001) found mean TAN values of 0.23 and 0.74 mg/L in ponds fertilized with different regimes which are similar to the result of low input ponds, the higher value of TAN in high input system might be due to the same reason as in case of TN.

Nitrate-nitrogen values of high input ponds were slightly higher than those of low input ponds during most months except October, when the value in high input ponds shot up and fell sharply next month and again showed similar trend of shooting up in January and sharp fall in next month. No noticeable change occurred in the nitrate-nitrogen values of low input ponds. The mean values of high and low input ponds were 0.20 and 0.028 mg/L, respectively (Table 1) which are comparatively lower than the result found by Kohinoor *et al.* (1999). Nitrite-nitrogen fluctuations in low and high input ponds were almost similar to the trends observed in case of nitrate-nitrogen in low and high input ponds (Fig. 8). Mean nitrite-nitrogen in low and high input systems were 0.003 and 0.13 mg/L, respectively. Yang Yi *et al.* (2001) recorded nitrite-nitrogen to range from 0.01-0.05 mg/L in low input system.

Total phosphorus level in high input ponds was higher than that of low input ponds (Fig. 12). The mean values in low and high input system were 1.10 and 4.17 mg/L, respectively (Table 1). Phosphate-phosphorus level in high input ponds was higher than that of low input ponds except in January and February (Fig. 10). The values of high input ponds decreased in zigzag fashion and more or less similar trend was observed in case of low input ponds too. The mean values of high and low input ponds were 0.27 and 0.83 mg/L, respectively (Table 1). Kohinoor *et al.* (1999) recorded a phosphate-phosphorus range between 0.14 and 0.53 mg/L in low input systems.

Very little fluctuation was observed in the values of chlorophyll-a in low input ponds (Fig. 11). Though the level of chlorophyll-a in high input ponds was higher in comparison to the low input ponds, the fluctuation was not high, except in September, when the value increased sharply and dropped in next month. Then it decreased gradually up to January and increased slightly in February. The mean values of chlorophyll-a in low and high input ponds were 100 and 491 μg/L (Table 1). During September, TP in high input ponds reached to a peak level, which was the reason for high value of chlorophyll-a in high input ponds in the same month.

Input-output study

The mean pond input and output of low input system (9,235 and 1,526 Kg/ha, respectively) were significantly different from those of high input system (72,818 and 32,460 Kg/ha, respectively) (Table 2). Chinese experiences present that pond output of 10 ton fish/ha consumed input of 75 ton duck manure or 454 ton pig manure or 550 ton cattle manure/ha (Korn, 1996). The mean pond input and output in cash Taka of low input system (18,542 and 48,903 Taka/ha, respectively) were significantly different from those of high input system (6,41,243 and 13,03,760 Taka/ha, respectively) (Table 2). Though the mean pond input of low input system.in non-cash Taka (15,752 Taka/ha) was significantly different from that of high input system (4,59,631 Taka/ha). The mean pond output in non-cash Taka of low input system (19,617 Taka/ha) was not significantly different from that of high input system (13,691 Taka/ha). Significant differences were also observed among average pond input, output in total cash Taka of low input system (34,169 and 68,520 Taka/ha, respectively) and those of high input system (11,00,874 and 13,17,450 Taka/ha, respectively) (Table 2).

Table 2. Input-output status (mean value ± S.E.) in low and high input systems

Parameters	Low input systems	High input systems	Level of significance
Pond input in Kg/ha	9234.67 ± 3018.54	72818.00 ± 5159.70	S (P<0.001)
Pond input in Cash Taka/ha	18542.33 ± 5846.03	641243.33 ± 58485.01	S (P<0.001)
Pond input in Non-cash Taka/ha	15751.67 ±9430.51	459631.00± 47998.41	S (P<0.001)
Pond input in Total cash Taka/ha	34169.37 ± 3647.89.	1100874 ± 52924	S (P<0.001)
Pond input in Kg N/ha	73.67 ± 17.03	2024.67 ± 76.60	S (P<0.001)
Dike input in Kg/ha	6552.67 ± 487.18	7135.33 ± 159.95	NS (P>0.05)
Dike input in Cash Taka/ha	3130.33 ± 1186.97	3533.00 ± 1036.08	NS (P>0.05)
Dike input in Non-cash Taka/ha	3934 .33 ± 663.93	3597.67 ± 71.61	NS (P>0.05)
Dike input in Total cash Taka/ha	7064.68 ± 1793.95	7131.09 ± 1057.68	NS (P>0.05)
Pond output in Kg/ha	1526.33 ± 229.84	32459.67 ± 574.48	S (P<0.001)
Pond output in Cash Taka/ha	48903.33 ± 4934.22	1303760.00 ± 64828.70	S (P<0.01)
Pond output in Non-cash Taka/ha	19617.00 ± 11460.76	13690.67 ± 6069.05	NS (P>0.05)
Pond output in Kg N/ha	36.00 ± 4.00	690.33 ± 30.55	S (P<0.001)
Dike output in Kg/ha	7788.00 ± 2441.04	6971.33 ± 4195.82	NS (P>0.05)
Dike output in Cash Taka/ha	37521.67 ± 18071.56	54415.00 ± 30313.91	NS (P>0.05)
Dike output in Non-cash Taka/ha	33327.67 ± 11128.91	10545.33 ± 6138.22	NS (P>0.05)
Pond: gross income Taka/ha	68520.47 ± 16076.41	1317450.40 ± 65894.65	S (P<0.001)
Pond : net income Taka/ha	34351.22 ± 18478.70	216575.97 ± 48906.82	S (P<0.05)
Pond: cost-net income ratio	1.107 ± 0.65	0.1981 ± 00	NS (P>0.05)
Dike: gross income Taka/ha	70849.46 ± 10724.89	64960.42 ± 31863.80	NS (P>0.05)
Dike : net income Taka/ha	63784.78 ± 12317.09	57829.33 ± 30892.70	NS (P>0.05)
Dike: cost-net income ratio	11.22 ± 4.33	7.38 ± 2.93	NS (P>0.05)

The mean pond input and output in Kg N of low input system were 74 Kg N/ha and 36 Kg N/ha, respectively, which were significantly different from those of high input system (2,025 and 690 Kg N/ha, respectively) (Table 2). Therefore, better utilization of nitrogen took place in low input system.

The mean dike input and output of low input system in biomass were 6,553 and 7,788 Kg/ha, respectively, and in cash 3,130 and 37,522 Taka/ha, respectively. The same in non-cash were 3,934 and 33,328 Taka/ha, respectively (Table 2). The mean dike input and output of high input system in biomass were 7,135 and 6,971 Kg/ha, respectively, in cash 3,533 and 54,415 Taka/ha, respectively and in non-cash 3,598 and 10,545 Taka/ha, respectively (Table 2). These differences were not significantly different. In integrated pond-dike system in the Zhujiang Delta, China, the dike input of 90-180 tons/ha composted household waste was used and obtained 10-80 ton/ha vegetables as output (Korn, 1996).

The mean net income from ponds of low input system was 34,351 Taka/ha and that of high input system was 2,16,576 Taka/ha, and the difference was significant ($P < 0.05$). However, the mean value of total cost-net income ratio in low input system was 1.107 and not significantly different from that of high input system of 0.19. The mean net income from dikes of low input system was 63,785 Taka/ha, which was not significantly different from that of high input system with 57,829 Taka/ha. Total cost-net income ratio of dikes in low input system was 11.22, which was not significantly different from that of high input system with 7.38.

Fig. 1 Mean transparency fluctuations in low and high input ponds.

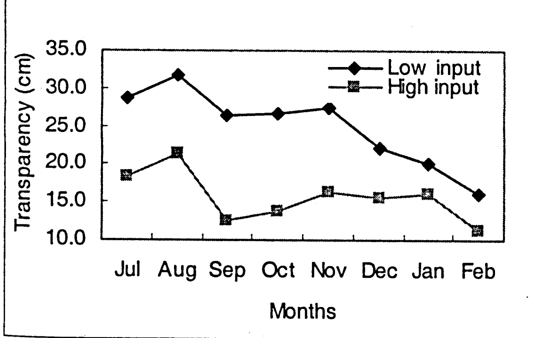


Fig. 2 Mean temperature fluctuations in low and high input ponds.

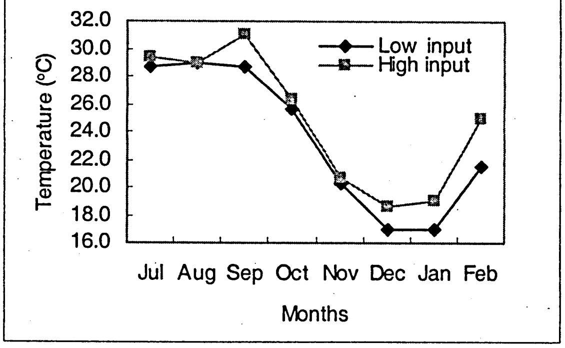


Fig. 3 Mean Total alkalinity fluctuations in low and high input ponds.

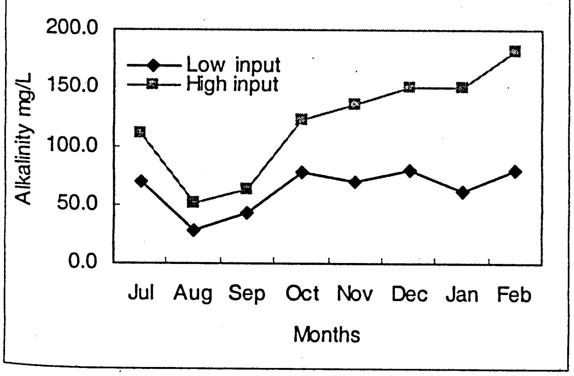


Fig. 4 Mean pH fluctuations in low and high input ponds.

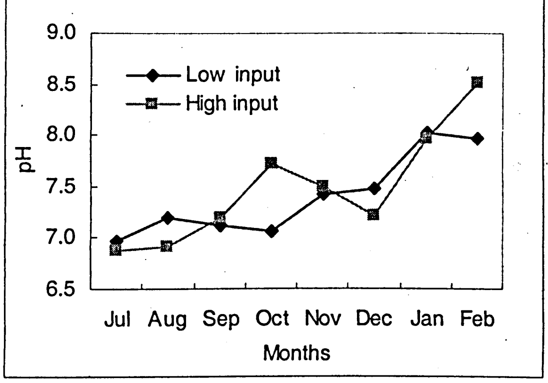


Fig. 5 Mean Dissolved Oxygen (DO) fluctuations in low and high input ponds.

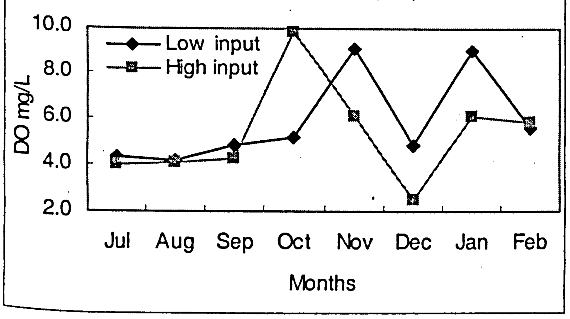
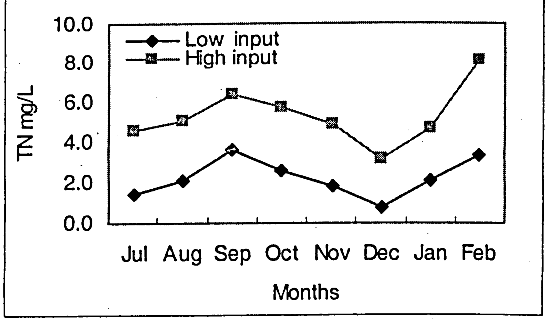


Fig. 6 Mean Total Nitrogen (TN) fluctuations in low and high input ponds.



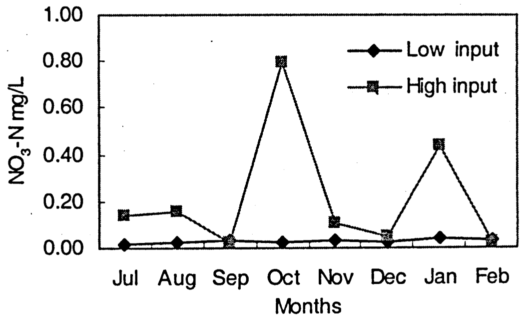


Fig. 7 Mean Nitrate-Nitrogen (NO_3-N) fluctuations in low and high input ponds.

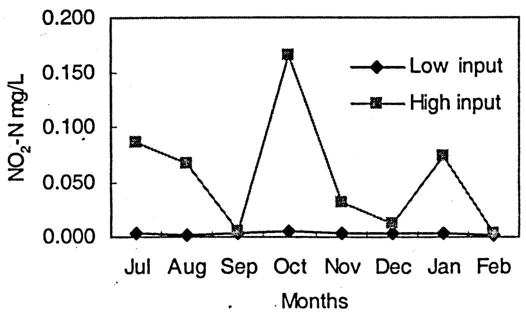


Fig. 8 Mean Nitrite-Nitrogen (NO_2-N) fluctuations in low and high input ponds.

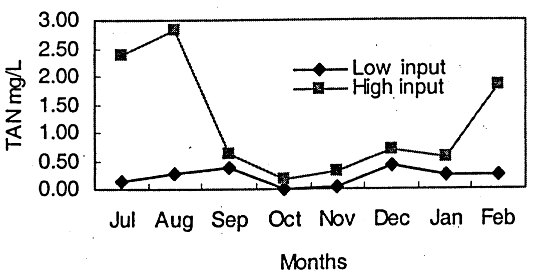


Fig. 9 Mean Total Ammonia Nitrogen (TAN) fluctuations in low and high input ponds.

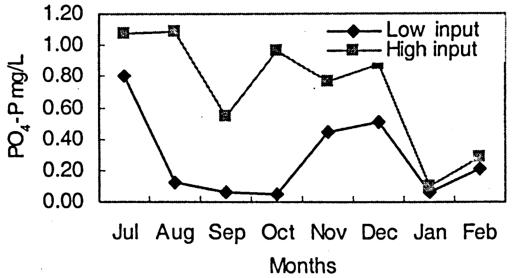


Fig. 10 Mean Phosphate-Phosphorus (PO_4-P) fluctuations in low and high input ponds.

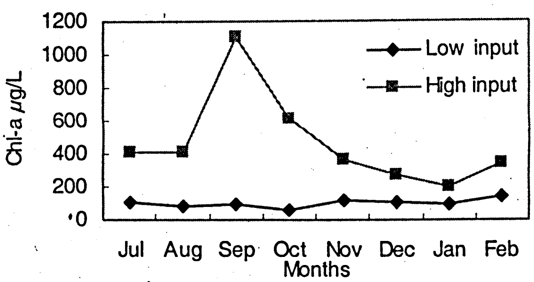


Fig. 11 Mean Chlorophyll-a (Chl-a) fluctuations in low and high input ponds.

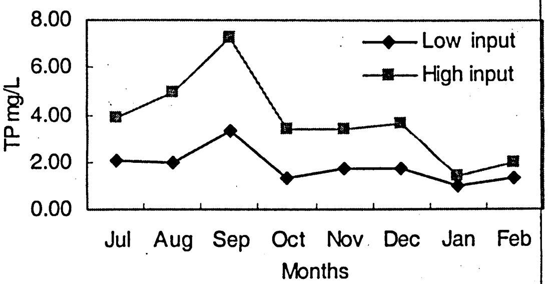


Fig. 12 Mean Total Phosphorus (TP) fluctuations in low and high input ponds.

The prime pond input in low input system was organic manure and the pelleted feed was in case of high input system. In low input ponds the use of input was irregular and poor due to lack of knowledge, fund and under utilization of the resources at least what they possessed. Whereas the input use in high input system was regular though the benefit derived from the used inputs was not optimum. `The benefit of high input system could be maximized through the reduction of use of expensive commercial feed ingredients and using locally available cheap agricultural wastes. In low input system the inputs like inorganic fertilizers, organic manure etc. used in dike could be replaced by nutrient rich pond mud and water if those inputs were used for pond production. The nutrient rich pond water and mud remained underutilized may deteriorate environment.

The average per hectare production of carp as pond output in low input system was lower in comparison to 3.6 ton/ha production recorded in carp polyculture with fertilization (Hassan *et al.*, 1997), which could be ameliorated either by increasing the use of household resources or agricultural by-products like rice bran, oil cake, wheat bran, kitchen waste, green leaves etc. as external inputs. In high input system, per hectare production was 32.46 ton/ha, which was higher than the production (9.97 ton/ha) obtained in an experimental *Pangasius* sp. and carp polyculture (Rahman, 1992).

The dike cropping in low input system was diversified i.e. different types of crop, for example amaranth, gourds, ladies finger, bean, etc., were produced. In high input system usually crop like papaya or banana was produced (with exception of producing small quantity of gourd). As a result, production was lower in comparison to low input system, although there are greater potentials of increased and diversified dike cropping in high input system could be done through the use of rich pond mud and water. Most production systems, especially the more intensive types, are inefficient, only about 30% of nutrient inputs being converted into harvestable products, the remainder being lost to the sediments, effluent water and the atmosphere (Beveridge *et al.*, 1993; Acosta-Nassar *et al.*, 1994; Olah *et al.*, 1994).

Economic aspect

Though the simple economic comparison between two systems revealed that the economic return per unit cash was higher in low input system, but the cash return per hectare was higher in high input system with the high investment. Therefore, both systems may be practiced provided all options for improvement and sustainability are exploited properly. Low input system is suitable for the poor farmers and the rich farmers may follow the high input system for higher production.

It may be concluded that per hectare pond input in biomass (Kg) in high input system was higher than that of low input system. Per hectare pond output in biomass (Kg) was also higher in high input system in comparison to that of low input system. Although the cash return per hectare in high input system was higher (with higher investment in high input system) than that of low input system, the return per unit cash was higher in low input system than that of high input system. Per hectare dike output in biomass was higher in low input system than that of high input system, though the difference was not significant. Per hectare dike income in low input system was also higher than that of high input system. Total nitrogen and chlorophyll-a levels in high input system were significantly higher in high input system than that of low input system, indicating the quality of pond water and mud of high input ponds was more productive. Considering all the facts and figures, it may be concluded that the low input system was more profitable in comparison to high input system. The poor farmers may follow this system giving special attention to increase per hectare pond production through proper use of resources. As per hectare pond production was higher in high input system and as a result gross income was higher also, the rich farmers may follow it with special attention to the best utilization of the productive pond water and mud to increase per hectare production through utilization of pond dikes.

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