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Optimisation of stocking density of Thai silver barb (*Barbodes gonionotus* Bleeker) in the duckweed-fed four species polyculture system

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Abstract

The optimisation of stocking density of Thai silver barb (*Barbodes gonionotus*) in the polyculture with *Labeo rohita*, *Catla catla* and *Cyprinus carpio* was investigated in seasonal ponds. Three different stocking densities of Thai silver barb i.e., 5,000, 6,000 and 7,000 fingerlings ha^{-1} were tested with stocking density of carps fixed at the rate of 10,000 fingerlings ha^{-1}. Duckweed was applied to all ponds supplemented with rice bran and oil cake. There were no significant variations on either water quality parameters or abundance of planktonic organisms due to the different stocking densities of silver barb. A significantly higher fish production ($p<0.05$) was recorded in the ponds in which medium stocking density of Thai silver barb was maintained.

Key words: *Barbodes gonionotus*, Stocking density, Polyculture, Duckweed

Introduction

Polyculture of fish has been practised with the aim that different species stocked in the ponds occupy different niches with their complementary feeding habits, utilising all the natural food available in the ponds and thus increasing the total fish production of the ponds (Sinha and Gupta 1975). Species composition and stocking density are important factors for the maximum fish production in polyculture. Several species compositions, usually with 6-7 species of carps, are practised in the polyculture systems of Bangladesh. These polyculture systems based on large number of species have developed without true scientific basis. It is rather an outcome of trial and error. Both native and exotic species are stocked together, many of them have been found antagonistic to each other (Wahab and Ahmed 1991, Wahab *et al.* 1994), and exert dietary overlap (Dewan *et al.* 1991). Moreover, farmers are often disappointed following complex nature of the technology, and find it difficult to obtain fingerlings of all species at their time of stocking. To overcome this situation, efforts have been made to develop a four species polyculture technique for Bangladesh with fast growing and compatible species of carps and Thai silver barb (Haque *et al.* 1998, Azim *et al.* 1998), which may exert synergistic effects (Milstein 1990) in the polyculture and thus enhance fish production.

Several experiments carried out under this project have revealed that two Indian major carps, rohu and catla, and two exotic species, common carp and Thai silver barb are highly compatible for semi-intensive polyculture system (Haque *et al.* 1998, Azim *et al.* 1998). It was observed that an addition of 2,500 fingerlings ha^{-1} of silver barb in polyculture has slightly decreased the growth of Indian major carps while increased that of common carp and overall fish production in the polyculture (Haque *et al.* 1998). In a recent study, Azim and Wahab (1998) reported that application of duckweed as pond input enhanced not only the growth of Thai silver barb but also that of rohu, catla and common carp in the polyculture where an equal stocking density for each species was maintained. Further, Azim *et al.* (1998) reported that duckweed can be used as an effective supplementary feed in the four species polyculture of carps with an addition of phytophagus Thai silver barb stocked at the rate of 5,000 fingerlings ha^{-1} and fed with duckweed. From the above findings, it is clear that inclusion of Thai silver barb could enhance the total fish production in polyculture provided duckweed is used as supplementary feed. Duckweed has been found helpful to compensate the adverse impacts of Thai silver barb in the carp polyculture. However, it remains uncertain about the optimum stocking density of Thai silver barb for a four species polyculture system which would ensure the optimum utilisation of duckweed as well as maximise the production of fish from this newly proposed species combination. The objective of present experiment was to optimise the stocking density of Thai silver barb by comparing three stocking densities in the duckweed-fed carp polyculture system.

Materials and methods

Experimental ponds and their preparation

The experiment was carried out for a period of 120 days between July and October '97 in six earthen fish ponds adjacent to the Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh. Ponds were all equal in size and depth with pond area of 100 m^2 and average depth of 1.5 m. Ponds were initially cleaned and limed at the rate of 250 kg/ha. Then ponds got filled up with underground water. Before one week of fish stocking, ponds were fertilised with cattle dung, urea and TSP at the rate of 5,500, 125 and 100 kg /ha, respectively.

Stocking of fish and pond management

The ponds were randomly divided into three treatment groups: ponds 1 and 4 in treatment 1 (T_1), ponds 2 and 6 in treatment 2 (T_2), and ponds 3 and 5 in treatment 3 (T_3). Fingerlings of fish of different species were collected from local supplier and stocked in the ponds. Rohu (*Labeo rohita*), catla (*Catla catla*), common carp (*Cyprinus carpio*) and Thai silver barb (*Barbodes gonionotus*) were stocked at the number of 33, 33, 34 and 50, respectively in each pond of T_1; T_1 plus additional 10 fingerlings of Thai silver barb (T_2); T_2 plus additional 10 fingerlings of Thai silver barb (T_3).

Fish were fed at a rate of 3% body weight per day with rice bran and soaked mustard oil cake (2:1). Quantity of feed was adjusted fortnightly on the basis of sampled fish weights. Duckweed was supplied to the ponds in 1 m^2 floating bamboo enclosures and made available for 24 hours per day. Duckweed was established in a pond adjacent to the experimental site, harvested and added to the bamboo enclosures when needed. Ponds were fertilised fortnightly with cattle dung, urea and TSP at the rate of 5,500, 125 and 100 kg/ha, respectively.

Limnological parameters

A series of physico-chemical parameters, viz., temperature, transparency, dissolved oxygen (DO), total hardness, pH, total ammonia, nitrate nitrogen (NO_3-N), phosphate phosphorus (PO_4-P) and chlorophyll-*a* of pond water were determined fortnightly between 0900 and 1000 hrs on each sampling day. Temperature, and DO were measured by a digital DO meter (YSI model 58). Transparency and pH of water were measured by a secchi disc and a pH meter (Jenway model 3020), respectively. Total hardness was determined by titrimetric method (Stirling 1985). Water samples were filtered for nutrient analysis except total ammonia which was determined on unfiltered sample. Nutrients were analysed by a Spectrophotometer ((Milton Roy Spectronic model 1001 plus) following Stirling (1985). Chlorophyll-*a* was also analysed spectrophotometrically after acetone extraction (Stirling 1985)

Quantitative and qualitative analyses of phytoplankton and zooplankton were made fortnightly. Sampling for plankton collection was performed after every one week of fertilisation. Samples were collected by passing 5 litre of water from three locations of each pond at different depths (surface, middle and bottom) through a plankton net (mesh size 45μm). The concentrated plankton samples were preserved in small plastic bottles with 3% formalin. The number of plankton was estimated using a Sedgewick-Rafter counting cell (S-R cell). One ml concentrated sample was placed on to the counting chamber of the S-R cell (providing 1000 fields) and was left to stand for 15 minutes to allow the plankton to settle. Then the plankton on randomly selected 10 fields of the chamber were counted under a binocular microscope (Swift M-4000). The number of plankton was calculated using the following formula:

$$N = \frac{P \times C \times 100}{L}$$

where, N is the number of plankton cells or units per litre of original water; P is the total number of plankton counted in 10 fields; C is the volume of final concentrate of the sample in ml; and L is the volume of the original water in litre. Identifications of plankton up to genus level were done according to Bellinger (1992).

Growth of fish

Fish samples were collected with a seine net fortnightly to estimate the growth in length (cm) and weight (g) for adjusting the quantity of feed application and to check up the health condition of fish. At the end of the experiment, all fish were harvested by de-watering the ponds.

Statistical analysis

For statistical analyses of data, a one-way ANOVA, and Duncan's multiple range test (DMRT) were applied using the statistical package, STATGRAPHICS version 7.

Results

Water quality parameters

Water quality parameters in all culture ponds throughout the experimental period are shown in Table 1. Temperature difference among the treatments was not significant (F=0.057) Secchi values varied significantly (F=3.55; $p<0.05$) among the treatments with the higher mean value in T_3 followed by T_2 and T_1. Further analysis of secchi data using Duncan's multiple range test showed that significant differences were confined between T_1 and T_3.

Table 1. Average (±SE) water quality parameters of different treatments

Treatments/density	T_1 (Lower)	T_2 (Medium)	T_3 (Higher)
Temperature (^{0}C)	29.97±0.38	29.78±0.39	29.96±0.39
Transparency (cm)	29.22±1.13	31.38±1.24	33.66±1.16
Total hardness (mgl^{-1})	124.77±6.37	119.77±3.93	114.44±4.24
pH	7.20	7.46	7.47
Dissolved oxygen (mgl^{-1})	5.37±0.10	5.31±0.10	5.42±0.12
NO_3-N (mgl^{-1})	1.12±0.05	1.12±0.04	1.16±0.03
Total ammonia (mgl^{-1})	0.21±0.049	0.20±0.045	0.18±0.054
PO_4-P (mgl^{-1})	0.18±0.006	0.18±0.004	0.18±0.005
Chlorophyll-*a* (µgl^{-1})	122.43±15.89	95.13±17.34	95.06±13.48

There was no significant variation (F=1.080) in the total hardness of the ponds water among different treatments. pH of water was around neutral and these values were not significantly different when compared using ANOVA (F=0.519). Dissolved oxygen (DO) did not vary significantly (F=0.268) among the treatments.

Mean values of total ammonia were not significantly different (F=0.084) among the treatments. Nitrate nitrogen did not vary significantly (F=0.319) among the treatments. Ortho-phosphate of pond waters were almost similar among the treatments during the study period. Mean values of chlorophyll-*a* in different treatments were not significantly different (F=0.347).

Plankton

Mean (±SE) abundance of plankton in different treatments are presented in Table 2. The phytoplankton population of the fish ponds comprised of four major groups: Bacillariophyceae (6), Chlorophyceae (31), Cyanophyceae (10) and Euglenophyceae (2). Mean abundance of Bacillariophyceae did not vary significantly (F=0.850) when compared using ANOVA. Mean abundance of Chlorophyceae varied significantly

($F=3.806$; $p<0.03$) with the higher mean value in T_1 followed by T_3 and T_2. Cyanophyceae was the most dominant group in all treatments in terms of abundance. These values were not significantly different when analysed statistically ($F=2.397$). When compared using ANOVA, Euglenophyceae showed no variation among the treatments ($F=1.159$). However, mean abundance of total phytoplankton was slightly higher in T_2 followed by T_1 and T_3 but these values were not statistically significant ($F=0.819$).

Table 2. Mean abundance (+SE cells l^{-1}) of plankton of different treatments

Treatments/density	T_1 (Lower)	T_2 (Medium)	T_3 (Higher)
Phytoplankton			
Bacillariophyceae	9468.75±1111.93	14206.25±4826.62	9375.00±1549.52
Chlorophyceae	30406±3453.32	17781.25±2419.09	23718.75±3696.55
Cyanophyceae	54781.25±13637.56	29656.25±7331.39	27843.75±6629.43
Euglenophyceae	20656.25±10108.75	8500.00±1396.42	10968.75±1655.46
Total phytoplankton	115531.25±17498.48	125406.25±50499.07	71906.25±10683.05
Zooplankton			
Crustacea	2575.00±265.75	3312.50±410.47	3500.00±442.53
Rotifera	8625.00±1345.90	7875.00±1108.20	10781.25±1519.98
Total Zooplankton	11312.50±1498.52	11187.50±1341.54	14281.25±1767.74

The zooplankton only comprised of Crustacea and Rotifera. Rotifera dominated in all the three treatments. There was always lower zoo-planktonic abundance in the fish ponds. Total zooplankton from different treatments were compared and no significant difference ($F=1.283$) was observed.

Growth and yield of fish

Yield parameters of different fish species under the three treatments are shown in Table 3. Based on the number of fish harvested at the end of the experiment, survival ranged from 66.17 to 90.90%. Rohu and catla showed more or less similar and higher survival among the treatments with the mean values of 90.90, 90.90 and 87.84% for rohu and 87.87, 90.90 and 86.35% for catla in lower (T_1), medium (T_2) and higher (T_3) stocking density, respectively. Common carp had lower survival in all treatments with the mean values of 67.64, 72.05 and 66.17% in T_1, T_2 and T_3, respectively. All fish species except Thai silver barb did not vary significantly in respect of survival rate among the treatments. The mean survival of Thai silver barb varied significantly ($p<0.05$) with a higher mean value of 87.50% in T_2 followed by 85.00% in T_1 and 78.57% in T_3. Further analysis of survival data of silver barb using Duncan's multiple range test showed no significant difference between T_1 and T_2.

Table 3. Yield parameters of various fish species under different treatments

Treatment/ Density	T_1 (Lower)				T_2 (Medium)				T_3 (Higher)			
Species	Rohu	Catla	C. carp	Silver barb	Rohu	Catla	C. carp	Silver barb	Rohu	Catla	C. carp	Silver barb
No. at stocking	33	33	34	50	33	33	34	60	33	33	34	70
No. at harvest	30	29	23	42.5	30	30	23.5	52.5	29	28.5	22.5	55
%Survival	90.90	87.87	67.64	85.00	90.90	90.90	72.05	87.50	87.84	86.35	66.17	78.57
Wt. at stocking (g)	1.87	4.86	3.49	1.61	1.85	4.83	3.51	1.63	1.84	4.91	3.52	1.66
Wt. at harvest (g)	135.37	222.07	159.84	122.02	140.16	221.38	152.59	118.26	111.53	183.93	140.91	96.31
Wt. gain/fish (g)	133.50	217.21	156.35	120.41	138.31	216.55	149.08	116.63	109.69	179.02	137.39	94.65
Net yield (kg/pond)	4.005	6.300	3.600	5.117	4.150	6.500	3.507	6.123	3.181	5.102	3.091	5.206
Net yield (Kg/ha)	400.5	630.0	360.0	511.7	415.0	650.0	350.7	612.3	318.1	510.2	309.1	520.6
Total (kg/ha/ 120 days)	1902.2				2028.0				1658.0			

A significant difference in weight was observed in mean increase in biomass of all fish species. Rohu was found to show distinct variation in weight gain, with a higher mean value of 138.31 g in T_2 followed by 133.50 g in T_1 and 109.69 g in T_3. Catla showed the best growth performance in all treatments when species-wise comparison was made. Weight gain per fish in T_1, T_2 and T_3 were 217.71, 216.55 and 179.02 g, respectively. There was no significant difference between T_1 and T_2. The growth of common carp varied to a small extent with the mean values of 156.35, 149.02 and 137.39 g in T_1, T_2 and T_3, respectively. Thai silver barb was found to show significant variation ($p<0.05$) with a higher mean value of 120.41 g in T_1 followed by 116.63 g in T_2 and 94.65 g in T_3. However, there was no significant difference between T_1 and T_2.

The relative contributions of different fish species in different treatments are illustrated in Fig. 1. Net yield of fish per hectare was extrapolated from the data of the 100 m^2 pond over a period of 120 days, and found that there was a wide difference in net yield of fish among three treatments, with 1,902, 2,028 and 1,658 kg/ha in T_1, T_2 and T_3, respectively. The relative contribution of each species of fish as shown in Table 3, showed that catla in T_1 and T_2, and Thai silver barb in T_3 were the highest, Thai silver barb in T_1 and T_2 and catla in T_3 were the second highest contributors to the pond production in this experiment. Rohu ranked third and common carp ranked the last in all treatments in respect of the relative contribution to the total production of fish. Rohu varied significantly ($F=129.673$; $p<0.001$) among the treatments with the higher mean value of 415 kg ha^{-1} in T_2 followed by 401 kg ha^{-1} in T_1 and 318 kg ha^{-1} in T_3. However, there was no significant variation between T_1 and T_2. Similar results were observed in case of catla and common carp.

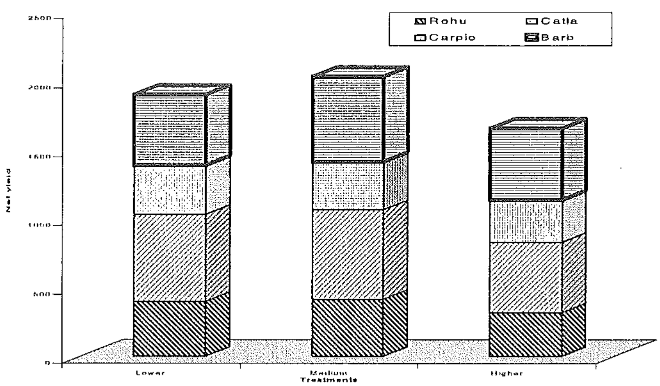

Fig. 1. Relative contributions of different fish species to the total fish production in different treatments

Net yield of catla was significantly lower ($F=47.977$; $p<0.005$) in T_3 than either T_1 or T_2. Catla contributed 630, 650 and 510 kg ha^{-1} in T_1, T_2 and T_3, respectively. Net yield of common carp was significantly higher ($F=10.161$; $p<0.05$) in T_1 with the mean value of 360 kg ha^{-1} followed by 351 kg ha^{-1} in T_2 and 309 kg ha^{-1} in T_3. Further analysis using DMRT revealed that there was no significant variation between T_1 and T_2. Thai silver barb was found to contribute significantly higher production ($F=42.36$, $p<0.01$) in T_2 with the mean value of 612 kg ha^{-1} followed by 521 kg ha^{-1} in T_3 and 512 kg ha^{-1} in T_1. However, there was no significant variation between T_1 and T_3.

Discussion

During the experimental period, it was observed that there was a little variation among the physico-chemical factors except transparency in respect of different stocking density of Thai silver barb but these were within the acceptable range for fish culture. The causes of higher secchi depth reading in T_3 might be due to the lower abundance of phytoplankton in the ponds where increased number of silver barb was stocked.

Phytoplankton was composed of four groups, Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae. Mean abundance of Chlorophyceae was significantly higher in T_1 but the causes were uncertain. In the present study, phytoplankton population showed inverse relationship with zooplankton population.

The survival rates of all fish species in all three treatments were from 66.17 to 90.90%. Survival rate of Thai silver barb was significantly lower in T_3 where the highest number of fish were stocked. The lowest survival was observed in case of common carp in all treatments.

Weight gain per fish of catla, common carp and Thai silver barb were higher in T_1, in which the lowest stocking density was maintained. However, these values were significantly different from T_3 but not from T_2. Individual weight gain of rohu was almost similar in T_1 and T_2 but different from that of T_3. This might be due to the additional numbers of silver barb which may have decreased the availability of food materials and space for other species and this species itself.

Among the four fish species, rohu, catla and Thai silver barb showed the highest net yield in T_2 and common carp showed the highest yield in T_1. The overall increase in total fish production in T_2 may have been due to the synergistic interaction resulted from faecal input of silver barb and the confounding effects of additional numbers of silver barb. This statement may not be extended in case of T_3 in which additional 7,000 silver barb were stocked. Inter-specific and intra-specific competition for food and space may have reduced the growth and production of all fish species. Duckweed was provided in order to mitigate any possible impacts resulting from addition of silver barb, since they are known to feed on both filamentous algae and higher aquatic plants (Hickling 1971; Journey *et al.* 1990). In addition, supplemental feed at the rate of 3% of total biomass was also applied to the ponds with a view that if there is any antagonistic effects of Thai silver barb (Haque *et al.* 1998) on other carps would be minimised.

From the present study, it may be concluded that the addition of duckweed and supplemental feed (rice bran and oil-cake) may compensate any inter-specific and intra-specific dietary competition and enhance the overall fish production within certain limits of stocking of Thai silver barb in the proposed four species polyculture system. The overall highest production was obtained from an additional stocking of Thai silver barb at the rate of 6,000 fingerlings ha^{-1} rather than 5,000 fingerlings ha^{-1} and 7,000 fingerlings ha^{-1} with a stocking density of carps at 10,000 fingerlings ha^{-1} in the polyculture system.

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