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Assessment of growth and production potential of Indian butter catfish *Ompok bimaculatus* as a substitute for mrigal *Cirrhinus mrigala* in polyculture of Indian major carps

CHANDAN DEBNATH, KIRAN DUBE*, NEELAM SAHARAN*, VIRENDRA KUMAR TIWARI*, MRINMOY DATTA AND LOPAMUDRA SAHOO
ICAR Research Complex for North-East Hill Region, Tripura Centre , Lembucherra - 799 210, Tripura, India
**ICAR-Central Institute of Fisheries Education,Versova, Mumbai - 400 061, Maharashtra, India*
e-mail: chandannath23@gmail.com

ABSTRACT

The growth and production of Indian butter catfish *Ompok bimaculatus*, popularly known as 'pabda' with Indian major carps (IMCs, catla, rohu and mrigal) was evaluated with an aim to introduce this fish into carp-based polyculture systems. Nine earthen ponds of similar dimensions were used for this study. The duration of culture was eight months and three species compositions, *viz.,* catla, rohu and mrigal (4:3:3) (T1), with 100% replacement of mrigal with pabda (T2) and 50% replacement of mrigal with pabda (T3) were used. The overall fish stocking density was 7500 fingerlings per ha. The fish were fed with farm-made feed (21.8% CP) @ 2-4% of their body weight. Pabda attained highest growth and survival in T2 and the introduction of pabda did not affect the overall survival, growth and production of catla and rohu. It also did not affect the overall fish production in terms of quantity ($p \geq 0.05$) in all the treatments. The dietary overlapping indices between the co-habiting fishes were insignificant across the treatments except for pabda and mrigal in T3 (0.74). Thus, it is concluded that co-culture of pabda and IMCs is possible by replacing mrigal partially or fully to have a higher return in terms value from the carp-based culture system.

Keywords : Butter catfish*,* Growth rate, Indian major carps, Pond culture, Survival

Introduction

Indian butter catfish *Ompok bimaculatus*, popularly known as '*pabda*' is a high value indigenous catfish of Tripura and it was declared as the '*State fish*' of Tripura mainly to promote awareness and conservation of the native stock (Lakra *et al*., 2010). Among the three popular species of the genus *Ompok viz., O. pabda, O. pabo* and *O. bimaculatus*; *O. bimaculatus* can grow to a bigger size and attracts consumer preference and higher price. This fish forms a delicacy in this region due to its superior taste and flavour. Besides being a high value food fish, it has good preference as an ornamental fish. Like other tropical catfishes, it breeds in the rivers, brooks, wetlands and lakes during monsoon. The wild stock of *O. bimaculatus* is waning fast because of reckless fishing and habitat destruction (NBFGR, 2011).

Aquaculture is the potential proposition for conservation and rehabilitation of depleted populations of pabda. However, for culture of *O. bimaculatus,* it is necessary to know the influence of various biotic and abiotic factors (Molur and Walker, 1998). The monoculture of the fish is productive and remunerative following a stocking density of 40,000 fingerlings per ha (Debnath *et al*., 2015) and 30% CP feed (Debnath *et al.,* 2018a, b). However, the seed availability and seed costs are quite high. Further many fish farmers prefer carp-based farming in this region. The local preference is to consider pabda as a minor component in their production system. In this situation, it is deemed necessary to know more about performance of the fish in carp-based culture systems. Co-culture of pabda and carps is suggested as a better option by Kohinoor *et al*. (1997). Therefore, the present study was carried out to assess the growth and production of pabda with Indian major carps in the existing polyculture practice of this region.

Materials and methods

Experimental site and design

Nine earthen ponds of uniform shape (rectangular), area (0.03 ha), depth (1.5 m) and basin conformation were used for the trial at ICAR Research Complex for NEH (ICAR RC NEH) Region, Tripura Centre, Lembucherra, West Tripura. Duration of the trial was eight months. The ponds for treatment 1 (T1) were stocked with catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala)* in the ratio 4:3:3, in treatment 2 (T2) mrigal was completely replaced by pabda and in treatment 3 (T3) 50% of mrigal was replaced with 50% pabda. Size of the fingerlings at the time of stocking was 8.66 cm/11.77 g in catla, 8.03 cm/9.83 g in rohu, 7.40 cm/8.03 g in mrigal and 4.13 cm/1.66 g in pabda.

Pond preparation, stocking and management

All ponds were dewatered and the aquatic weeds were removed before commencement of the trial. Lime (CaO) was applied @ 250 kg ha^{-1} as a basal dose and @ 100 kg ha^{-1} in three-months interval and a higher dose (@200 kg ha^{-1}) before the winter season. Pond fertilisation was with cattle manure @ 3000 kg ha^{-1} and single super phosphate (SSP) @30 kg ha^{-1} as basal dose, later fortnightly with cattle manure (@500 kg ha^{-1}), urea (@10 kg ha^{-1}) and SSP (@15 kg ha^{-1}) till harvest. Seepage and evaporation loss of water in the ponds was compensated periodically and maintained the desired water depth till the end of the trial.

The fingerlings were stocked @7500 nos. ha^{-1} and a formulated feed with 50% rice bran, 30% mustard oil cake, 19% fish meal and 1% vitamin-mineral mixture was used for feeding. Proximate composition of the feed was protein - 21.8%, crude lipid - 4.84%, crude fibre - 9.68%, ash - 19.55% and NFE - 44.13%. Feeding rate was 4% of the fish biomass during the first 2 months, 3% in next 2 months and 2% in last 4 months of the culture period.

Water, soil and plankton analysis

Fortnightly water quality parameters like temperature, dissolved oxygen and pH were monitored directly by a portable water analyser (Merck, Germany) and transparency with a Secchi Disc. Total alkalinity and inorganic nutrients were estimated using test kits (Merck, Germany). The soil quality of the ponds was tested for pH, available N, available P and organic carbon at the beginning and at the end of culture following standard methods (APHA, 1998). Both phytoplankton and zooplankton were analysed following the direct census method (Jhingran *et al*., 1969).

Estimation of fish growth and production

Monthly, total length and weight of ten live specimens for each species were recorded by random sampling. The specific growth rate (SGR) was calculated following method of Brown (1957) and food conversion ratio (FCR) of Castell and Tiews (1980). After eight months, ponds were partially drained and harvested completely. Fishes were counted and estimated the survival rate, species-wise fish production and overall fish production.

Estimation of dietary overlap between the co-habiting species

Samples of three specimens of each species were collected monthly and preserved in 10% neutral buffered formalin. Later the gut contents were taken out into a petri-plate, diluted with 20 ml distilled water and one ml subsample was taken using a Sedgwick-Rafter cell counter, identified and counted the food items using stereo zoom and compound microscopes (Leica S6 and Leica DM 1000). The dietary overlapping index was calculated following the method of Schoener (1970). The index value ≥ 0.6 was considered significant.

Data analysis

The data were analysed using the SPSS (v.21) and presented as mean±S.D. One-way ANOVA was done setting the level of significance at 95% ($p<0.05$) to compare difference between the means of different treatments. A simple cost-benefit analysis was done at the prevailing market rate to estimate the profit from different culture systems.

Results

Water quality

The level of water temperature, transparency, pH, dissolved oxygen, total alkalinity, ammonia, nitrate, nitrite and phosphate trivially varied ($p \geq 0.05$) among the treatments (Table 1). There were no abrupt changes in any of the water parameters tested in any of the ponds throughout the period of study.

Table 1. Water quality parameters (Mean±SE) in different treatments

Parameters	T1	T2	T3
Temperature (°C)	27.43 ± 0.018^a (16.7-32.8)	27.42 ± 0.007^a (16.6-32.8)	27.42 ± 0.05^a (16.6-32.8)
Transparency (cm)	48.09 ± 0.17^a (31.3-58.4)	48.37 ± 0.43^a (31.4-55.5)	48.05 ± 0.09^a (31.4-56.8)
pH	7.46 ± 0.01^a (7.2-7.6)	7.49 ± 0.01^a (7.3-7.7)	7.48 ± 0.02^a (7.2-7.6)
Dissolved oxygen (ppm)	5.03 ± 0.003^a (4.6-5.8)	5.03 ± 0.006^a (4.5-5.6)	5.03 ± 0.003^a (4.6-5.7)
Total alkalinity (ppm)	62.11 ± 0.08^a (48.2-71.8)	62.42 ± 0.55^a (45.5-72.4)	50.2-73.8 (62.12 ± 0.07^a)
NH_3-N (ppm)	0.39 ± 0.01^a (0.11-0.65)	0.38 ± 0.00^a (0.12-0.63)	0.39 ± 0.00^a (0.11-0.66)
NO_3-N (ppm)	0.22 ± 0.001^a (0.04-0.43)	0.22 ± 0.001^a (0.05-0.42)	0.22 ± 0.00^a (0.05-0.43)
NO_2-N (ppm)	0.027 ± 0.002^a (0.014-0.042)	0.013-0.043 (0.028 ± 0.004^a)	0.014-0.043 (0.028 ± 0.003^a)
PO_4-P (ppm)	0.28 ± 0.002^a (0.17-0.42)	0.28 ± 0.004^a (0.16-0.39)	0.27 ± 0.003^a (0.17-0.40)

Mean values having same superscripts in same row are not different significantly ($p \geq 0.05$)

Soil quality

There were no significant variations ($p \geq 0.05$) in soil pH, organic carbon, available N and available P content among the treatments at the beginning of the experiment. At the end of the culture period, pH, organic carbon, available N and P levels in the all ponds were found increased, however their differences among the treatments were insignificant (Table 2).

Plankton

The level of phytoplankton dominated over the level of zooplankton in all the ponds. Phytoplankton populations consisted mainly of 4 families (Table 3), *viz.,* Chlorophyceae, Cyanophyceae, Bacillariophyceae and Euglenophyceae. Chlorophyceae was the dominant group in the all ponds. The group-wise phytoplankton and the total phytoplankton density showed trivial variations among the treatments. Zooplankton populations were mainly from 2 groups *viz.,* Crustacea and Rotifera. Rotifera was the dominant group in all ponds.

Dietary overlap

The dietary overlapping index in combinations of catla-rohu, catla-mrigal, rohu-mrigal, catla-pabda and rohu-pabda were insignificant (≤ 0.6), whereas, in mrigal-pabda it was significant (≥ 0.6) (Table 4).

Fish growth and production

The yield attributes of the fishes in T1, T2 and T3 are presented in Table 5 and Fig. 1-4. The final length of fishes (Fig. 1a-5a) did not show significant variation ($p \geq 0.05$) among the treatments. The final weight of catla and rohu

Table 2. Soil quality parameters (Mean±SE) in different treatments

Parameters	Sampling time	T1	T2	T3
pH	Initial	6.56±0.05^{a} (6.50-6.60)	6.60±0.10^{a} (6.50-6.70)	6.63±0.57^{a} (6.60-6.70)
	Final	7.03±0.20^{a} (6.80-7.20)	7.03±0.11^{a} (6.90-7.10)	7.06±0.15^{a} (6.90-7.20)
Organic C (%)	Initial	0.50±0.05^{a} (0.44-0.55)	0.50±0.05^{a} (0.44-0.55)	0.52±0.06^{a} (0.46-0.58)
	Final	1.38±0.05^{a} (1.35-1.45)	1.40±0.06^{a} (1.33-1.45)	1.38±0.03^{a} (1.36-1.42)
Available N (mg%)	Initial	1.71±0.05^{a} (1.65-1.75)	1.70±0.05^{a} (1.65-1.75)	1.81±0.11^{a} (1.75-1.95)
	Final	38.90±4.96^{a} (35.50-44.60)	39.36±4.25^{a} (34.50-42.40)	42.63±0.58^{a} (42.20-43.30)
Available P (mg%)	Initial	0.77±0.17^{a} (0.62-0.96)	0.85±0.08^{a} (0.78-0.95)	0.81±0.04^{a} (0.76-0.85)
	Final	24.33±1.58^{a} (22.5-25.30)	25.13±1.48^{a} (23.50-26.40)	24.53±1.80^{a} (22.80-26.40)

Mean values having same superscripts in same row are not significantly different ($p \geq 0.05$)

Table 3. Plankton density (cells l^{-1}) (Mean±SE) in different treatments

Plankton groups	T1	T2	T3
Phytoplankton ($\times 10^3$ cells l^{-1})			
Chlorophyceae	4.39±0.08^{a} (4.30-4.45)	4.52±0.07^{a} (4.47-4.61)	4.42±0.03^{a} (4.39-4.46)
Cyanophyceae	1.48±0.08^{a} (1.39-1.54)	1.45±0.07^{a} (1.39-1.54)	1.43±0.09^{a} (1.39-1.54)
Bacillariophyceae	0.40±0.01^{a} (0.39-0.43)	0.40±0.03^{a} (0.36-0.43)	0.40±0.02^{a} (0.36-0.44)
Euglenophyceae	0.12±0.008^{a} (0.12-0.13)	0.13±0.007^{a} (0.12-0.13)	0.12±0.01^{a} (0.11-0.13)
Total phytoplankton	6.40±0.07^{a} (6.34-6.49)	6.51±0.17^{a} (6.41-6.71)	6.43±0.11^{a} (6.29-6.47)
Zooplankton (x10^3 individual l^{-1})			
Rotifera	1.54±0.03^{a} (1.51-1.56)	1.54±0.01^{a} (1.54-1.56)	1.54±0.02^{a} (1.53-1.56)
Crustacea	0.42±0.07^{a} (0.35-0.49)	0.41±0.03^{a} (0.39-0.45)	0.38±0.03^{a} (0.36-0.43)
Total zooplankton	1.97±0.05^{a} (1.91-2.00)	1.96±0.02^{a} (1.95-1.99)	1.93±0.01^{a} (1.93-1.95)

Mean values having same superscripts in same row are not significantly different ($p \geq 0.05$)

Table 4. Dietary overlapping index (Mean±SE) between fish in different treatments

Interaction	T1	T2	T3
Catla-Rohu	0.35±0.08	0.32±0.06	0.36±0.05
Catla-Mrigal	0.21±0.06	-	0.25±0.01
Rohu-Mrigal	0.28±0.05	-	0.29±0.03
Catla-Pabda	-	0.29±0.06	0.33±0.01
Rohu-Pabda	-	0.31±0.03	0.27±0.04
Mrigal-Pabda	-	-	0.74±0.08

Values ≥ 0.6 indicated significant overlapping and possible competition between the co-habiting fish

(Fig. 1b, 2b) alone was higher ($p \leq 0.05$) in T2 compared with T3 and T1. The weight of mrigal (Fig. 3b) was higher ($p \leq 0.05$) in T3 when compared with T1. The weight of pabda (Fig. 4b) was higher ($p \leq 0.05$) in T2 when compared with T3. There was no significant difference ($p \geq 0.05$) in the survival rate (Table 5) of catla and rohu among the treatments. The survival of pabda (Table 5) was highest in T2 and the survival of mrigal was highest in T3. The SGR (Table 5) of catla was higher ($p \leq 0.05$) in T2 when compared with T1 and T3. In rohu, no such difference was noticed among treatments. The SGR of mrigal was higher ($p \leq 0.05$) in T3 when compared with T1. In pabda, SGR was higher ($p \leq 0.05$) in T2 compared with T3. The species-wise fish production (Table 5) showed variation among the treatments, however, the overall fish production was statistically same ($p \geq 0.05$). Food conversion ratio (Table 5) did not show significant variation among the treatments. The net profit (Table 6) assessed from the production, considering the average market value of carps as ₹200 kg^{-1} and pabda as ₹500 kg^{-1} was highest in T2 (₹2.2 lakhs ha^{-1}) and lowest in T1 (₹1.8 lakhs ha^{-1}).

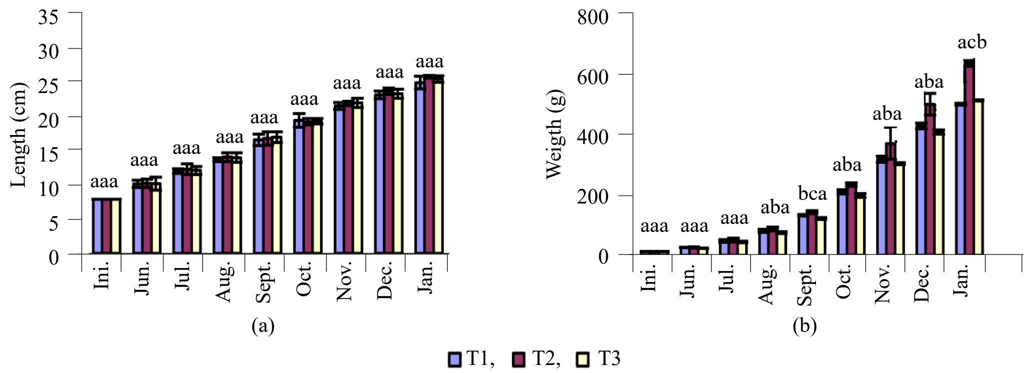

Fig. 1. Monthly length (a) and weight (b) attainment in catla. Bars bearing same superscripts in a month are not different ($p \geq 0.05$)

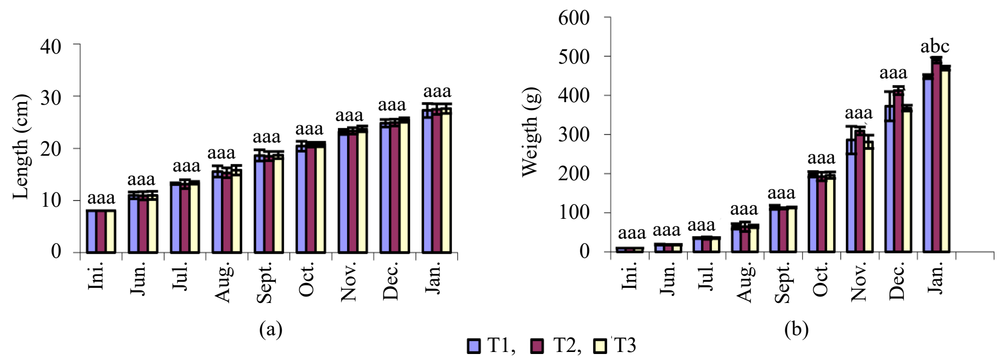

Fig. 2. Monthly length (a) and weight (b) attainment in rohu. Bars bearing same superscripts in a month are not different ($p \geq 0.05$)

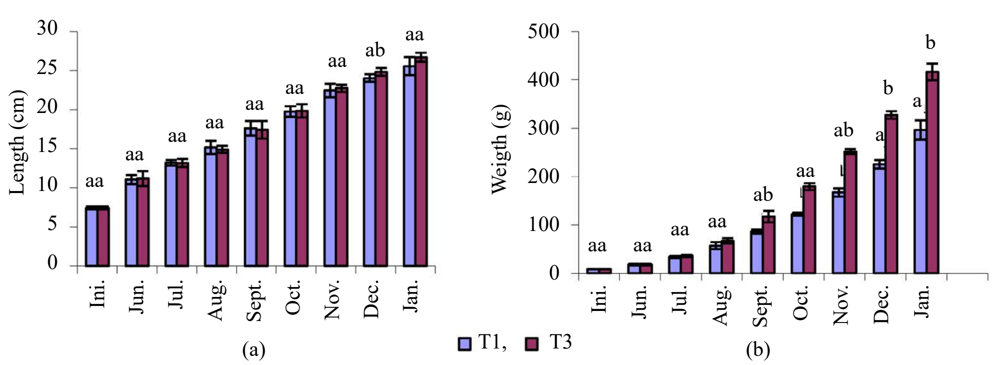

Fig. 3. Monthly length (a) and weight (b) attainment in mrigal. Bars bearing same superscripts in a month are not different ($p \geq 0.05$)

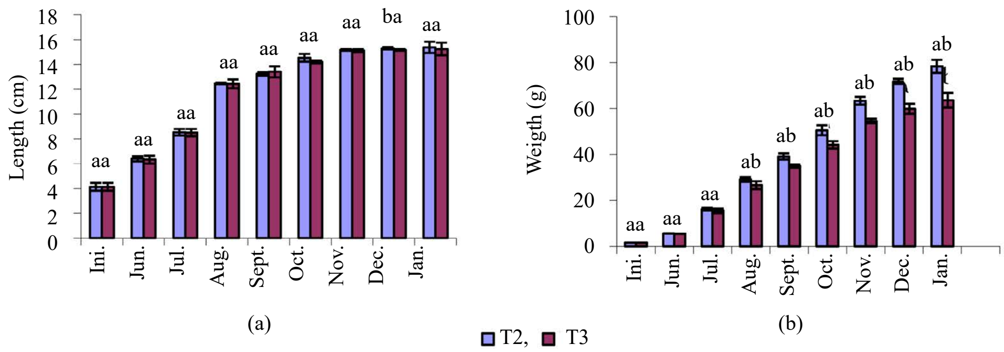

Fig. 4. Monthly length (a) and weight (b) attainment in pabda. Bars bearing same superscripts in a month are not different (p≥0.05)

Table 5. Yield attributes (Mean±SE) of fish in different treatments

Parameters	Treatments		
	T1	T2	T3
Specific growth rate, SGR (% day^{-1})			
Catla	1.55±0.02^a (0.50-2.69)	1.65±0.02^b (0.77-2.73)	1.56±0.05^a (0.73-2.43)
Rohu	1.56±0.009^a (0.59-2.18)	1.59±0.002^a (0.56-2.13)	1.57±0.003^a (0.79-2.10)
Mrigal	1.47±0.02^a (0.87-2.67)	-	1.61±0.01^b (0.77-2.73)
Pabda	-	1.57±0.014^a (0.27-4.03)	1.49±0.02^b (0.19-3.99)
Survival (%)			
Catla	78.00±4.00^a (74-82)	77.00±6.24^a (70.76-83.24)	79.00±3.60^a (75.4-82.60)
Rohu	80.00±4.58^a (75.42-84.58)	80.00±2.64^a (77.36-82.64)	78.33±5.85^a (72.48-84.18)
Mrigal	71.33±3.05^a (68.28-74.38)	-	83.00±4.58^b (78.42-87.58)
Pabda	-	81.33±4.04^a (77.29-85.37)	67.33±6.11^b (61.22-73.44)
Species-wise fish production (kg ha^{-1})			
Catla	1243.82±55.59^a (1188.23-1299.41)	1558.08±104.24^b (1453.84-1662.32)	1290.22±63.71^a (1226.51-1353.93)
Rohu	805.61±42.98^a (462.63-848.59)	882.18±37.88^a (844.3-920.06)	826.69±54.32^a (772.37-881.01)
Mrigal	475.18±29.01^a (446.17-504.19)	-	388.48±20.49^b (367.99-408.97)
Pabda	-	143.51±12.06^a (131.45-155.57)	48.08±1.96^b (46.12-50.04)
Total fish production (kg ha^{-1})	2524.61±43.81^a (2480.8-2568.42)	2583.77±707.51^a (1876.26-3291.28)	2553.47±538.90^a (2014.57-3092.37)
Food conversion ratio (FCR)	2.25±0.07^a (2.18-2.32)	2.26±0.01^a (2.25-2.27)	2.27±0.01^a (2.26-2.28)

Mean values having same superscripts in same row are not different (p≥0.05)

Discussion

Water and soil quality parameters of the aquaculture system have direct influence on the growth and survival of the fish (Brett, 1979). Therefore, proper water and soil quality management is important in the fish culture system. Here in this trial, water quality parameters of all ponds were within the desirable limits for fish farming and there were no abrupt anomalies in any of the parameters observed. The water temperature (16.7-32.8°C) and ammonia were comparable to those reported by Debnath *et al*. (2015) from the same locality, transparency to Boyd (1990), dissolved oxygen and pH to Jena and Das (2011) and the contents of the inorganic nutrients to Rahman *et al*. (2011a). Ammonia accumulation in the water was slightly higher during the winter months which might be due to the 'plankton die-off' with the fall of water temperature as reported by Boyd and Tucker (1992), however, it remained within the acceptable range for pisciculture.

The soil quality parameters *viz.,* pH, organic carbon, available N and available P showed ideal condition for fish

Table 6. The cost and benefit analysis (₹) calculated from different treatments

Items	Treatments		
	T1	T2	T3
A. Costs			
Pond lease (ha yr^{-1})	25000	25000	25000
Pond clearance	30000	30000	30000
Lime	12000	12000	12000
Manure	23000	23000	23000
Fertilisers	6825	6825	6825
Fingerlings	18000	24750	21375
Feed	130815	132459	116320
Labour	72000	72000	72000
Miscellaneous	10000	10000	10000
Total	327640	336034	316520
B. Gross benefit			
Table fish*	504800	559500	524800
C. Net benefit	177160	223466	208280

*Local market price for carps@ ₹200 kg^{-1} and pabda @ ₹ 500 kg^{-1}

growth and survival and were similar to those reported by Jena *et al*. (2002) from Odisha. The change in the level of available N and available P showed similar trends across the treatments indicating there was homogeneous pond fertilisation and liming schedule across the treatments. Increase of N and P concentrations at the end of culture could be a result of the gradual deposition of fish metabolites and spillage of a portion of nutrients from the feed and fertilisers (Sahu *et al*., 2007).

Density of plankton indicated optimum availability of natural food for fishes throughout the culture (Sahu *et al*., 2007). The higher levels of phytoplankton indicated higher productivity. Phytoplankton count consistently dominated over zooplankton in all ponds due to regular pond fertilisation and feeding (Keshavanath *et al*., 2002) and the zooplanktivorous nature of pabda (Parameshwaran *et al*., 1970) did not show any significant change in the zooplankton density from T2 and T3. Rich plankton population indicated optimum use of organic manure as well as inorganic fertilisers.

Variations in the levels of water and soil quality parameters were almost identical across the treatments. This is largely due to uniform shape, size, depth, basin conformation and contour and uniform management of the experimental ponds (Murty *et al*., 1978). There was no incidence of blooming in the ponds, which indicated the quantity of feed or fertilisers applied in the ponds were either inadequate to affect the water quality adversely or it was adjusted in the pond ecosystem in course of fish culture (New, 1987). The protein level of the feed in this trial (21.8%) was sufficient enough to hold carp-based pond culture and it can be assumed that it had almost no negative effect on all the fish species. Moreover, carps prefer plankton over artificial feed in the pond-based culture system (Rahman and Rahman, 2003).

Slight reduction in the growth and survival of pabda and mrigal was recorded in T3 when compared to T4 and similar impact for mrigal also was noticed in T3 compared to T1. This is mainly due to the competition between pabda and mrigal for food and living space as both naturally cohabit in the same niche of the pond ecosystem (Parameswaran *et al*., 1970; Chandra and Haq, 1986). This is also axiomatic with the significantly higher value of dietary overlapping index between these fishes (Wallace and Ramsey, 1983; Rahman *et al.,* 2011b).

Catla being a surface feeder and rohu being column feeder, did not make any difference in the growth and survival of pabda (Kumar, 1992). These carps showed similar growth trends across the treatments due to no overlapping in their feeding and living niches. The incorporation of pabda had apparently positive effect on the growth and production of these carps. The ejections of pabda might have enhanced the nutrient availability and plankton production which might have directly influenced the growth and production of catla and rohu as reported in similar cases of co-culture with *Puntius gonionotus* by Haque *et al*. (1998) and *Sperata seenghala* by Rahman *et al*. (2011b).

The SGR of pabda was 1.49 in T3 and 1.57 in T2. This is comparatively low than the previous report from monoculture by Debnath *et al*. (2015). This clearly indicated the influence of carps in the growth and production of pabda. More precisely, the presence of mrigal reduced the survival in pabda from 81.33 (T2) to 67.33% (T3) which also confirms the negative impact of mrigal on pabda in the trials.

The growth rates and survival were fairly high in all the treatments which can be attributed to quality of fish seeds used for stocking and adequate management practices followed like maintenance of water quality parameters, feeding and pond fertilisation (Rahman *et al*., 2011b). The overall fish production in different treatments varied from 2524-2583 kg ha^{-1} with no significant difference among the treatments which also indicated that pabda can be a component in carp-based culture system. Profit derived in T2 and T3 were higher than T1, which indicated that the addition of pabda in the culture system, supported the production in terms of value due to the high consumer preference of pabda (Pradhan *et al*., 2014). Addition of pabda, did not significantly influence the production of catla and rohu which confirm the possibility of pabda as a potential candidate for introduction in carp-based culture systems.

Co-culture of pabda in the ratios, density and combinations used in this trial did not significantly affect production of IMCs in the polyculture system. It significantly increased the production in terms of value indicating increase in profit of co-culture of pabda with IMCs. Among the IMCs, mrigal alone showed significant overlapping in the food items with pabda which clearly caution about the balancing of stocking ratio of these two species. The study also confirms that both 50 as well as 100% replacement of mrigal with pabda did not show significant impact in the total production in terms of biomass, but it clearly increased the production in terms of value.

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