J. Asiat. Soc. Bangladesh, Sci. **47**(1): 1-12, June 2021 DOI: https://doi.org/10.3329/jasbs.v47i1.54182

GROWTH PERFORMANCES AND NUTRIENT COMPOSITIONS OF PABDA *OMPOK BIMACULATUS* (BLOCH, 1797) GROWN IN RECIRCULATING AND CLOSED AQUACULTURE SYSTEMS

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Abstract

This study evaluated the growth performances and nutrient compositions of pabda *Ompok bimaculatus* (Bloch, 1797) in a recirculating aquaculture system (RAS) and a closed aquaculture system (CAS). The average daily weight gain (ADG) and specific growth rate (SGR) of pabda in RAS (ADG: 0.18 g/d; SGR: 3.40 %/d) was 3.61- and 1.41-folds higher than that of the CAS (ADG: 0.05 g/d; SGR: 2.40 %/d). Fish had significantly higher level of PUFA (Poly-unsaturated fatty acid) in CAS (41%) than in RAS (33%). The ratio between omega-3 and omega-6 fatty acids in RAS and CAS were 0.73 and 0.69, respectively. This study's results have demonstrated that the culture of pabda in RAS is more suitable than CAS in terms of growth.

Key words: Pabda, Growth, Nutrient compositions, RAS, CAS

Introduction

The inland aquaculture of Bangladesh accounted for 56.24% of the total fish yield during 2017-18 (DoF 2019). Although pond aquaculture accounting the highest percentage of fish production, average pond production is still low (lower than 5 tons/ha) (DoF 2019). Pond production can be increased many folds by adopting intensive cultural techniques such as recirculating aquaculture system (RAS). RAS and closed aquaculture system (CAS) are both closed systems of aquaculture. The closed aquaculture system refers to the land-based rearing of aquatic species in raceways, tanks, and ponds. Recirculation of water is held in RAS, while wastewater is removed periodically in CAS. The advantages of RAS include improved waste water management opportunities and recycling of nutrient (Piedrahita 2003), control of biological pollution (Zohar *et al.* 2005),

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consumption of reduced water (Verdegem *et al.* 2006), improving fish welfare (Martins *et al.* 2010), maintenance of better hygiene and management of disease (Summerfelt *et al.* 2009, Tal *et al.* 2009), improvement of production efficiency and reduction in work intensity (McKenzie *et al.* 2012, Suhr and Pedersen 2010).

Pabda *Ompok bimaculatus* is a high value cultured fish having good taste and flavor with great demand and price. This fish is listed in the IUCN Red book as the threatened fish of Bangladesh as an endangered species (IUCN 2015). Pabda has been farming in the ponds except for RAS and CAS that can be adopted as the solutions to increase production as well as improvement of growth performance and nutritional quality.

Luo *et al.* (2014) have observed the growth, welfare, digestive activity, and partial cost-effectiveness of genetically improved farmed tilapia (*Oreochromis niloticus*), cultured in a recirculating aquaculture system and an indoor bio-floc system. The growth and welfare of rainbow trout (*Oncorhynchus mykiss*) have been reported in recirculating and flow-through rearing systems by d'Orbcastel *et al.* (2009). The nutritional status of the wild *O. bimaculatus* has been investigated by Alam *et al.* (2016). Although the culture of pabda in the RAS system has started in the last five years, its performances, for example, pabda growth and nutritional qualities, have not been reported. Therefore, there is a need to compare the growth performances and nutritional qualities of pabda in RAS and CAS.

The objectives of this study were to determine the growth performances of cultured pabda in RAS and CAS systems; analyze proximate composition; detect amino acid and fatty acid profiles.

Materials and Methods

Experimental fish and procedures: Pabda were used as a study fish because of its high value and farming in Bangladesh in recirculating aquaculture system (RAS) for the last 5 years. Fry of the fish was collected from Sharnalata Matshya Hatchery, Trishal, Mymensingh, Bangladesh. The experiment was undertaken from July to October 2017 in RAS and closed aquaculture system (CAS) for four months.

Culture systems: Three tanks of RAS (10,000 L capacity) were used by filling with 10,000 liters tap water, while three concrete tanks were used for CAS as the experimental systems. In CAS, each small tank was 10 × 6 × 21/4 ft, filled with 650 liters of tap water.

Culture station: The fish was reared in RAS in the Agro 3 Fish Hatchery and Culture Farm, Mymensingh. However, the CAS experiment was undertaken in the wet laboratory of Zoology Section, Biological Research Division, Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka.

Experimental design: This was a 2 × 4 factorial study in triplicate. The fixed factors were RAS and CAS and four culture months. Growth performances were measured by ADG (average daily weight gain), SGR (specific growth rate), FCR (feed conversion ratio) and well-being or condition factor (*K*).

Stocking density: Each RAS tank and CAS tank was stocked with a fish fry at the rate of 1 fish/L, i.e., 10,000 and 650 fries, respectively. The initial average weight and length of a fish were 0.35 g and 1.25 cm, respectively. Before stocking, the fry was acclimatized for 6 hours in a flow-through tank system in clean water. After that, they were slowly released into the tanks. No feed was given on the first day of stocking.

Feeding of fish: In both systems, fish were fed the same commercial diet (Tongwei, China). Fish were fed with powdered feed at 10% of body weight (BW) in the 1st month and pellet feed at 4% BW in the 2nd & 3rd months and 2% BW in the 4th month.

Sampling design: Fish samples (10 fish/tank) were drawn every month with a fine meshed net. Individual length (cm) was measured by using a measuring scale and weight (g) by an electronic balance. At the end of the experiment, the final length (cm) and weight (g) of the individual fish were also recorded.

Water quality variables: Water quality variables of CAS were monitored at every 7 days interval. The dissolved oxygen (DO) concentration and water temperature (°C) of each tank were measured by using a portable DO meter. The level of pH was measured by a digital pH meter. Light intensity was measured by using a light intensity meter.

Fish growth performances: Final body weight and length of 10 fish were recorded from each tank after harvest. The observed body weight and food intake data were used to calculate the following growth indices:

1. Average Daily Weight Gain (ADG) = $W_2 - W_1/ T_2 - T_1$
2. Specific Growth Rate (SGR) = $(\ln W_2 - \ln W_1/ T_2 - T_1) \times 100\%$
3. Feed Conversion Ratio (FCR) = Feed (g) consumed by fish/ Weight (g) gain of fish
4. Condition factor (*K*) = $(W/ L^3) \times 100$

Where, W_2 = Final body weight (g) of fish at time T_2 (day), W_1 = Initial body weight (g) of fish at time T_1 (day), W= Body weight in gram (g), L= Body length in centimeter (cm).

Biochemical composition of the fish muscle: The studies fish (Pabda) of our experiment was a small indigenous species (SIS), so we collected the whole muscle to make a pull sample for analysis. Moisture and ash were measured following the methods described by AOAC (2000). The crude protein content was assayed by measuring nitrogen (N, 6.25) using the Kjeldahl method (Kjeldahl 1883), and the crude lipid content was measured by the Floch method using chloroform: methanol (2:1) (Folch *et al.* 1957). The amino acid profiles were determined using an automatic amino acid analyzer following the protocol established by SYKAM S4300, The Czech Republic. Fat was extracted into the ether and then methylated to fatty acid methyl esters (FAMEs). Gas chromatography (GC) was used to measure FAMEs quantitatively (Dodds 2005).

Statistical analysis: Percent data were transformed into the square root before statistical analysis. Means between systems were compared by t-test, while among months by ANOVA followed by Tukey's HSD post hoc for multiple comparisons. The Statistical Package for the Social Sciences (SPSS) v. 20.0 software package (SPSS, SAS Institute Inc. Gary, USA) and Microsoft office excel 2007 were used for statistical analysis. The level of significance was at 5%.

Results and Discussion

Average daily gain (ADG, g/day): The average daily weight gain (ADG) of pabda reared in the RAS system, which was more than 3.61 times higher than those cultured in the CAS regardless of the culture duration (Table 1). The fish grew better in the first month of stocking and had no significant difference to the fourth month regardless of the system. ADG of the fish sampled in the second and third months showed no significant difference (Table 1).

In RAS, the sample's ADG observed in the first and fourth months was similar but significantly higher than did the third month (Table 1). However, ADG found in the second month was not significantly different from the first and fourth months.

In CAS, the highest ADG was observed in the first month of stocking, while the lowest ADG was found in the third month (Table 1). The level of ADG detected in the second and fourth months was not significantly different from the level of ADG measured in the third and the first months.

The observed high ADG in the RAS could have resulted from maintaining of water quality parameters at optimum level. Fish reared in the RAS might not have suffered from any potential stress resulting from water quality parameters. Optimum culture condition might have played a vital role in the digestion, absorption, and assimilation of the ingested feed stuffs. A better environmental condition might also have facilitated in regular eating feed stuffs. In contrast, CAS had a low DO level sometimes, particularly in the morning that could have exerted pressure. Besides, in CAS, the concentration of NH_3 has been found to rise above tolerance level. This increased NH_3 might have played a negative role in eating feed stuffs. In CAS, water was washed out partially for 15 days. This kind of use of the cultural environment might have stressed the fish not eating at their satiation level, which was not in the case of RAS circumstance.

Table 1. Average daily weight gain (ADG, g/day) of pabda *Ompok bimaculatus* sampled one-month intervals in two culture systems, RAS and CAS, respectively.

Culture duration (Months)	Culture systems		Overall
	RAS	CAS	
1	0.22 ± 0.029^{a}	0.07 ± 0.003^{a}	0.15 ± 0.036^{a}
2	0.15 ± 0.014^{ab}	0.05 ± 0.009^{ab}	0.10 ± 0.022^{bc}
3	0.11 ± 0.012^{b}	0.03 ± 0.009^{b}	0.07 ± 0.020^{c}
4	0.22 ± 0.022^{a}	0.04 ± 0.003^{ab}	0.13 ± 0.041^{ab}
Overall	$0.18 \pm 0.017_{a}$	$0.05 \pm 0.056_{b}$	0.11 ± 0.016

Values (mean ± SEM) with different subscripts letters in the row and superscripts letters in the column are significantly different (t-test, ANOVA, HSD; $p < 0.05$).

Over culture duration, the average daily weight gain (ADG) has been found to drop until the third month of culture duration but again rose at the last month. The observed highest ADG (0.15 ± 0.036 g/d) in the first month of stocking represents the exponential growth pattern of fish established by Dutta (1994).

Specific growth rate (SGR, %/day): The specific growth rate (SGR, %/day) of pabdareared in RAS (3.39 ± 1.12 %/d) was 1.41 times higher than those reared in CAS (2.40 ± 0.75 %/d) across the culture duration (Table 2). SGR of the fish in the first month was significantly higher than the other three months regardless of the system (Table 2). The level of SGR of the fish sampled in the second month was similar to that of the fourth month but significantly higher than in the third month.

In RAS, the SGR of the fish sampled in the first month of stocking was 5.85-, 11.17-, and 7.86-folds higher than did the second, third and fourth months, respectively (Table 2). However, the level of SGR observed in the following three months was not significantly different.

In CAS, the level of SGR measured in the first month of stocking was 4.15-, 16.34- and 12.10-times higher than in the second, third and fourth months (Table 2). However, the level of SGR detected in the third and fourth months was similar.

Table 2. Specific growth rate (SGR, %/day) of pabda *Ompok bimaculatus* sampled one-month intervals in two culture systems, RAS and CAS, respectively.

Culture duration (Months)	Culture systems		Overall
	RAS	CAS	
1	9.79 ± 0.410^{a}	6.61 ± 0.115^{a}	8.20 ± 0.736^{a}
2	1.67 ± 0.280^{b}	1.60 ± 0.258^{b}	1.63 ± 0.171^{b}
3	0.88 ± 0.109^{b}	0.60 ± 0.169^{c}	0.74 ± 0.109^{c}
4	1.25 ± 0.109^{b}	0.81 ± 0.081^{c}	1.03 ± 0.115^{bc}
Overall	$3.40 \pm 1.122_{a}$	$2.40 \pm 0.745_{a}$	2.90 ± 0.667

Values (mean ± SEM) with different subscripts letters in the row and superscripts letters in the column are significantly different (t-test, ANOVA, HSD; $p<0.05$).

Growth of fish across both systems has been found to maintain similar trends over culture duration in which fish grew fast in the first month of stocking that could be due to the exponential growth pattern. Dropped ADG in the later months of our study follows the growth trends of fish growth patterns reported by Rounsefell and Everhart (1953).

SGR in both RAS and CAS systems has been found to be similar, which denotes identical growth performance in both systems. As observed in this studied fish, SGR has a declining trend over the duration except for a slight increase in the last month. This declining trend of SGR with time indicates typical fish growth trends. The highest performance of fish in SGR in the first month could be due to powdered feed, which small fish have easily ingested. Powdered feed might be digested and absorbed well and finally assimilated to build the body tissue. The application of pellets from the second month of culture might have reduced SGR by reducing the later months' utilization efficiencies. GIFT (Genetically Improved Farmed Tilapia) tilapia *Oreochromis niloticus* had a 1.90% specific growth rate when reared in the RAS at 8.06 kg/t initial stocking density (Luo *et al.* 2014). Pabda, in the RAS of the present study, performed better in SGR (3.4% %/d) compared to tilapia. In a previous study, d'Orbcastel *et al.* (2009) demonstrated that rainbow trout *Oncorhynchus mykiss* had an overall SGR of 0.85% over a culture duration of 77 days, much lower than the present study.

Feed conversion ratio (FCR): FCR did not differ between culture systems across culture durations (Table 3).

Among months, the third month had the highest FCR (5.61±1.053) than those observed in the other three culture months (Table 3) across culture systems.

In RAS, the highest FCR (4.16±0.67) was observed in the third month, while the lowest level (0.87 ± 0.05) was measured in the first month of stocking (Table 3). However, levels of FCR found in the other two months were similar but significantly lower than the value of the third month.

Table 3. The feed conversion ratio of pabda *Ompok bimaculatus* sampled one-month interval in two culture systems, RAS and CAS, respectively.

Culture duration (Months)	Culture systems		Overall
	RAS	CAS	
1	0.87 ± 0.0513^b	0.98 ± 0.059^b	0.93 ± 0.290^b
2	1.99 ± 0.4625^b	2.11 ± 0.491^b	2.06 ± 0.303^b
3	4.16 ± 0.6657^a	7.06 ± 1.729^a	5.61 ± 1.053^a
4	1.35 ± 0.1339^b	2.24 ± 0.279^b	1.79 ± 0.243^b
Overall	$2.09 \pm 0.4707_a$	$3.10 \pm 0.837_a$	2.60 ± 0.482

Values (mean ± SEM) with different subscripts letters in the row and superscripts letters in the column are significantly different (t-test, ANOVA, HSD; $p<0.05$).

Like RAS, CAS had the highest FCR in the third month of culture duration (Table 3). Levels of FCR detected in the other three culture months were significantly lower than that of the third month but similar.

Fish performed better in converting feed into flesh in RAS than in CAS, although the difference was not significant. This better performance in RAS might have resulted from better water quality indices in the RAS than in the CAS. Slightly higher FCR, as observed in the CAS, indicates loss of feed due to uneaten by the fish. In RAS, tilapia had an FCR of 1.47, which was nearly 14% lower than the FCR found in the RAS of the present study (Luo *et al.* 2014).

Excess FCR in the third month of culture, as has been found in this study, could have resulted from excessive feed use. Due to weaning, fish were not eating the required quantity of feed after the first month when pellet feed was started to give. Moreover, fish were given feed at 4% of their body weight (BW) in the second and third months but 2% in the fourth month. So, in the fourth month, the fish has been eaten enough feed and thus lost was lower than the previous month. Therefore, loss of most feed in the third month of culture might be responsible for higher FCR.

Water quality parameters: In RAS, temperature, DO concentration, pH, NH_3 were always maintained 28-30ºC, 7-8 mg/l, 7-8 and <0.05 mg/l, respectively. In CAS, the observed range of temperature, DO conc., pH and light intensity were 28.57 ± 0.24°C to 32.27 ± 0.13ºC, 2.64 ± 0.08 to 7.36 ± 0.77 mg/l, 6.93 ± 0.19 to 8.54 ± 0.12 and 7.67 ± 1.20 to 24.00 ± 1.00 Lux; respectively.

Proximate compositions of fish muscle: The proximate compositions of the fish muscle are given in Table 4. Ash and crude lipid content in fish muscle were significantly higher in RAS than that of CAS. However, the proximate composition such as moisture content, ash content, crude protein content and crude lipid content of pabda followed the typical range as expected (DoF 2002).

Table 4. Proximate compositions (% wet basis) of the muscle of pabda *Ompok bimaculatus* sampled from two culture systems, RAS and CAS, respectively.

Proximate composition (% wet basis)	Culture system	
	RAS	CAS
Moisture	78.68 ±1.23$_a$	79.78 ± 0.37$_a$
Protein	16.41 ±1.35$_a$	15.47 ± 0.47$_a$
Ash	6.85 ± 0.59$_a$	3.74 ± 0.57$_b$
Lipid	3.77 ± 0.75$_a$	1.55 ± 0.10$_b$

Values (mean ± SEM) with different subscripts letters in the row are significantly different (t-test, p<0.05).

Amino acids: Of 8 essential amino acids, lysine, leucine and arginine were the major essential amino acids (EAAs) in the fish in both systems (Table 5).

Of non-essential amino acids (NEAAs), glutamic acid was found in the highest percentage in both systems (RAS: 18.38 ± 0.18**;** CAS**:** 16.31 ± 0.21) followed by aspartic acid (RAS: 11.26 ± 0.21; CAS: 11.93 ± 0.39) (Table 5).

Alam *et al.* (2016) have found similar levels EAAs in the same wild fish. Of the NEAAs, glutamic acid (15.28%) has been reported in the same wild fish, which is close to the present study's findings. Zhao *et al.* (2010) have found lysine (6.24%), leucine (5.78%) and arginine (4.20%) in the promfret *Pampus punctatissimus* that follows the trend of the findings of the present study.

Fatty acids: Of five monounsaturated fatty acids (MUFA), oleic acid was highest in both systems but did not differ significantly. CAS had 4.60- and 1.93-times higher palmitoleic acid and eicosenoic acid than RAS (Table 6).

Table 5. Amino acids (%) of the muscle of pabda *Ompok bimaculatus* sampled from two culture systems RAS and CAS, respectively.

Amino acids (%)	Culture systems	
	RAS	CAS
EAA		
Valine	5.89 ± 0.05	5.79 ± 0.31
Threonine	4.85 ± 0.12	4.82 ± 0.06
Histidine	2.95 ± 0.30	3.39 ± 0.59
Arginine	6.36 ± 0.19	6.06 ± 0.32
Phenylalanine	4.12 ± 0.13	4.44 ± 0.22
Lysine	10.70 ± 0.35	10.84 ± 0.31
Leucine	10.34 ± 0.43	9.59 ± 0.23
Isoleucine	6.22 ± 0.18	6.31 ± 0.14
NEAA		
Glutamic acid	$18.38 \pm 0.18_a$	$16.31 \pm 0.21_b$
Glycine	5.23 ± 0.13	5.00 ± 0.33
Proline	4.39 ± 0.16	4.57 ± 0.11
Alanine	6.56 ± 0.13	6.17 ± 0.07
Aspartic acid	11.26 ± 0.21	11.93 ± 0.39
Serine	3.88 ± 0.14	4.13 ± 0.15

Values (mean ± SEM) with different subscripts letters in the row are significantly different (t-test, $p<0.05$).

Among nine polyunsaturated fatty acids (PUFA), RAS had a significantly higher eicosatrienoic acid level than the CAS. However, CAS had significantly higher levels of α-linolenic acid and eicosadienoic acid. EPA and DHA between systems did not differ (Table 6).

The total percentage of PUFA in pabda was nearly 33% in RAS, which was significantly lower than that of CAS (41%). Similarly, MUFA was found to be significantly higher in CAS (32%) than did the RAS (20%). In RAS, saturated fatty acid (SFA) was 1.71-folds higher than in the CAS.

The difference in the fatty acid composition of pabda between two systems could be due to the difference in water quality, particularly water temperature (Zhao *et al.* 2010). Therefore, controlled water temperature in the RAS might have played a positive role in gaining a higher quantity of fatty acids in the fish than that of CAS.

Table 6. Fatty acids (%) of the muscle of pabda *Ompok bimaculatus* sampled from two culture systems, RAS and CAS, respectively.

Fatty acids (%)	Culture systems	
	RAS	CAS
SFA		
C14: 0 Myristic acid	$10.54 \pm 0.75_a$	$4.66 \pm 0.43_b$
C16: 0 Palmitic acid	$29.81 \pm 0.68_a$	$14.76 \pm 0.56_b$
C18: 0 Stearic acid	3.97 ± 0.06	3.57 ± 0.66
C20: 0 Arachidic acid	1.20 ± 0.07	2.22 ± 0.29
C23: 0 Tricosanoic acid	$0.72 \pm 0.21_b$	$1.82 \pm 0.11_a$
MUFA		
C14: 1 Myristoleic acid	0.82 ± 0.09	1.47 ± 0.45
C16: 1 Palmitoleic acid	$0.89 \pm 0.10_b$	$4.09 \pm 0.19_a$
C18: 1 Oleic acid	13.36 ± 1.85	17.99 ± 1.49
C20: 1 Eicosenoic acid	$2.55 \pm 0.36_b$	$4.92 \pm 0.21_a$
C22: 1 Erucic acid	2.81 ± 0.51	3.95 ± 1.02
PUFA		
C18: 2 Linoleic acid	3.12 ± 0.91	3.44 ± 0.79
C18: 3 γ-Linolenic acid	3.72 ± 0.40	4.56 ± 0.71
C18: 3 α-Linolenic acid	$3.26 \pm 0.06_b$	$7.01 \pm 0.31_a$
C20: 2 cis-11, 14 Eicosadienoic acid	$0.91 \pm 0.19_b$	$1.93 \pm 0.03_a$
C20:3 Eicosatrienoic acid	$8.11 \pm 0.17_a$	$6.98 \pm 0.08_b$
C20: 4 Arachidonic acid	5.71 ± 1.62	6.20 ± 1.09
C22: 2 cis-13, 16 Docosadienoic acid	1.57 ± 0.55	2.15 ± 0.95
C20: 5 Eicosapentaenoic (EPA)	3.09 ± 0.72	2.83 ± 0.71
C22: 6 Docosahexaenoic (DHA)	3.86 ± 1.05	5.48 ± 0.56
ω-3/ ω-6	0.73	0.69

Values (mean ± SEM) with different subscripts letters in the row are significantly different (t-test, $p<0.05$).

The presence of oleic acid is the highest percentage among the MUFA in pabda agrees with the findings of Alam *et al.* (2016) in wild pabda. Jabeen and Chaudhry (2011) have found 21-25% oleic acid in *Cyprinus carpio*, 10-18% in *Labeo rohita* and 11- 16% in *Oreochromis mossambicus*. The observed 41% PUFA in the experimental fish in CAS could have resulted from natural food such as phytoplankton and zooplankton that is similar to the finding of Alam *et al*. (2016) in the wild pabda. The presence of a lower level of PUFA in the fish raised in RAS could be due to the application of commercial feed only. In CAS, natural food organisms might have supplied additional PUFA.

The ratio between omega-3 and omega-6 fatty acids in RAS and CAS were 0.73 and 0.69, respectively (Table 6). The observed ratio between omega-3 and omega-6 fatty acids in RAS and CAS in the present study has been found to be higher than *Cyprinus carpio* (0.27), *Labeo rohita* (0.23) and *Oreochromis mossambicus* (0.23) (Jabeen and Chaudhry 2011). However, these levels (0.73 and 0.69) have been to be lower compared to wild (2.72) and farmed (5.10) yellow perch *Perca flavescents* (Gonzalez *et al*. 2006) that is due to the marine environment. Further, Usydus *et al.* (2012) reported that the ratio between omega-3 and omega-6 fatty acids must be above 0.25 for proper prophylactic properties of the fatty acids that have been ensured in the present study.

The culture of pabda in RAS could be beneficial in terms of the growth of fish compared to CAS. RAS may require lower culture duration to get the marketable fish, thus having three consecutive cycles of fish production in the same system over a year. Having three harvests will therefore reduce the production cost and make the system profitable. The culture of pabda in RAS may also reduce the feed cost by reducing FCR. Although the percentage composition of amino acids remains similar between RAS and CAS systems, a higher percentage of fatty acids was observed in RAS produced pabda.

Acknowledgements

The authors wish to thank the Ministry of Science and Technology, Govt. of the Peoples Republic of Bangladesh for their financial support to conduct this study. We are grateful to Mr. A. B. M. Shamsul Alam, Agro 3, Fish Hatchery and Culture Farm, Mymensingh, Bangladesh, for providing facilities to conduct the RAS experiment.

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(Revised copy received on 03.05.2021)