Project ID 410

Competitive Research Grant

Sub-Project Completion Report

on

Development of Sustainable Aquaculture Technique in the Inundated Low-lying Agriculture Land of the Coastal Region of Bangladesh

Project Duration
May 2017 to September 2018

Department of Fisheries Management
Patuakhali Science and Technology University
Dumki, Patuakhali-8602

Submitted to
Project Implementation Unit-BARC, NATP 2
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

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Citation

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Project Implementation Unit
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Bangladesh Agricultural Research Council (BARC)
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Acronyms

@	:	At the rate of
ANOVA	:	Analysis of Variance
AOAC	:	Association of Official Analytical Chemists
BARC	:	Bangladesh Agricultural Research Council
BDT	:	Bangladeshi Taka
°C	:	Degree Centigrade
CRG	:	Competitive Research Grand
cm	:	Centimeter
Co-PI	:	Co-Principal Investigator
DO	:	Dissolved Oxygen
%	:	Percentage
‰	:	Parts Per Thousand
±	:	Plus minus
FAO	:	Food And Agricultural Organization
FCR	:	Food Conversion Ratio
GoB	:	Government of Bangladesh
GDP	:	Gross Domestic Product
g	:	Gram
ha	:	Hectare
hrs	:	Hours
kg	:	Kilogram
L	:	Liter
LoA	:	Letter of Agreement
mg/l	:	Milligram Per Liter
m	:	Meter
N	:	Nitrogen
NATP	:	National Agricultural Technology Project
PI	:	Principal Investigator
PSTU	:	Patuakhali Science and Technology University
P	:	Phosphorus
PIU	:	Project Implementation Unit
PCR	:	Project Completion Report
RTC	:	Research and Training Centre
SD	:	Standard Deviation
SGR	:	Specific Growth Rate
SPSS	:	Statistical Package for Social Science
TK	:	Taka
USA	:	United State of America
USAID	:	United States Agency for International Development

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Executive Summary

The research was conducted to develop a sustainable aquaculture technology in the low lying inundated lands utilizing *Hygroryza aristata*, Floating grass as fish feed for reducing production cost. Three treatments (T_1, T_2 & T_3) were carried out for 12 months in inundated land (30dec. each treatment) partially fenced with bamboo split mat and knotless cot net. Fingerlings of Grass Carp (*Ctenopharyngodon idella*), Black carp (*Mylopharyngodon pisceus*), Common carp (*Cyprinus Carpio*) and Tilapia (*Oreochromis niloticus*) were stocked at the rate of 50 fish/dec. In treatment-1, *H. aristata,* Floating grass was planted on bottom soil to feed the fish readily; in treatment-2, Floating grass supplied from outside cultivated land and in treatment-3, commercial floating fish feed was applied at the rate 8% of the body weight for 1st two month and then reduced to 6% for 2nd two months and finally 4% for the rest of the culture period.

Production parameters such as initial weight, final weight, weight gain, % weight gain, survival rate, Food Conversion Rate (FCR), Specific Growth Rate (SGR) and other production performance of all cultured species in three different treatments were estimated as per experimental design. Proximate composition analysis of *H. aristata*, commercial floating feed and fish were performed to relate with growth performance. The gross and net productions were recorded with the highest 9060.70 $kgha^{-1}year^{-1}$, 8724.89 $kgha^{-1}year^{-1}$ in T_1 followed by 8469.70$kgha^{-1}year^{-1}$, 8141.06 $kgha^{-1}year^{-1}$ in T_3 and 8001.23 $kgha^{-1}year^{-1}$, 7669.21 $kgha^{-1}year^{-1}$ in T_2 during the study period. The highest production was exhibited by Grass Carp, 6499.12 $kgha^{-1}$ in T_1 followed by 5609.57 $kgha^{-1}$ in T_2 and 5217.06 $kgha^{-1}$ in T_3 where the contributions of this species to the total fish production were calculated 71.73%, 70.11% and 61.60% in T_1, T_2 and T_3 respectively. The highest specific growth rate (SGR % day-1) was recorded 1.31±0.05 in Tilapia in T_3 while it was recorded 1.13±0.03 and 1.12±0.05 in T_1 and T_2 respectively. Obviously, this highest specific growth rate of Tilapia was the result of applying costly supplementary feed in T_3 with a Food Conversion Ratio (FCR) of 1.62. Among the 3 treatments, the highest production performance was exhibited by T_1 was due to the direct utilization of *H. aristata*, floating grass in wet form as readily available feed for Grass carp and as serving as substrate for several aquatic biota such as insect, crustacean, zooplankton, mollusks etc. provided food for other fish species thus reduced feed cost. During proximate content analysis of *H. aristata*, 7.29±0.41%, 3.71±0.07 % crude protein and 28.97±0.86%, 8.23±0.17 % carbohydrate were obtained in dry and wet form basis respectively, where the commercial fish feed contained 28.53±0.14% crude protein and 37.32±0.05 % carbohydrate. The water quality parameters such as Temperature, Transparency, Dissolved oxygen, pH, Alkalinity, Nitrate, Phosphate, Salinity etc. were monitored fortnightly and found suitable for fish.

Therefore, the inundated low-lying agricultural in the southern-coastal region of Bangladesh may be used for aquaculture by utilizing Floating grass *Hygroryza aristata* as ready food for fish which will significantly reduce production cost owing to deducting feed cost.

CRG Sub-Project Completion Report (PCR)

A. Sub-project description

1. Title of the CRG sub-project:
Development of Sustainable Aquaculture System in the Inundated Low-lying Agriculture Land in the Coastal Region of Bangladesh

2. Implementing organization: Patuakhali Science and Technology University

3. Name and full address with phone, cell and E-mail of PI/Co-PI (s):

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4. Sub-project budget (Tk):

4.1 Total: TK. 2859290 (In word: Twenty Eight Lac Fifty Nine Thousand Two Hundred Ninety)
4.2 Revised (if any): Not applicable

5. Duration of the sub-project: From May 2017 to September 2018

5.1 Start date (based on LoA signed) : 8 May 2017
5.2 End date : 30 September 2018

6. Justification of undertaking the sub-project:

Bangladesh is considered one of the most suitable countries in the world for freshwater aquaculture because of its advantageous resources and agro-climatic environments (Ahmed *et al.,* 2012). The fisheries sector is significant for socio-economic enlargement, nutrition supplementation, employment generation, poverty alleviation and foreign exchange earning of Bangladesh (Hasan *et al.,* 2011). The sector contributes near about 60% of animal protein to the daily diets of the population, about 3.57% to GDP and 25.30% to the agriculture in 2017-18 while this sector provided full-time employment of 1.5

million and part-time employment of 16.5 million people which is about 11% of the total population in Bangladesh (DOF, 2018).

To meet the growing higher global demand for fish, world fisheries and aquaculture production reached 157 million tons in 2012 and is expected to reach about 172 million tons in 2021, with most of the growth from aquaculture (FAO, 2013). By 2030, addition of 2 billion more people to the world population will mean that aquaculture will require producing nearly double i.e. 85 million tons of fish per year just to maintain current consumption levels (FAO, 2007). It is estimated that the total feed cost in culture accounts for 30 to 70% of production cost, depending upon the type of culture system and intensity of feeding (De Silva and Aderson, 1995; El-Sayed 2004). In fact, the increasing price of feed ingredients (fishmeal, fish oil and cereal), energy and transportation costs have complicated the availability of aqua-feeds to many fish farmers worldwide. This global trend could influence small-scale producers to change businesses and/or result to poverty, vulnerability and loss of livelihood especially in developing countries (Rola and Hasan, 2007). However, it is threatening that sustainability of aquaculture depends on many factors, most important ones is cost effective feed (Daniel, 2018). Therefore, the development and sustainability of future aquaculture could significantly depend on the identification of new suitable low cost alternative plant protein ingredients that can replace fish meal without compromising the growth performance (Gatlin *et al*., 2007).

The southern coastal region of Bangladesh is important for aquaculture and livelihood of many people depend on it, but per hectare production of Carp fish from aquaculture is very low due to a number of reasons; the most important ones is high feed cost (Hossain *et al.,* 2014). Some parts of the agriculture lands of Barisal, Pirojpur, Gopalgonj, Jhalkathi, Patuakhali, Shariatpur and Madaripur districts remain inundated all the year round by tidal water and during the rainy season it contains 5-7 feet water and make huge area of water resources when growth rate of fish is very high, but during this time, these land remain completely unutilized and untouched in context to fish culture. This region is geographically and morphologically different and the soils are very fertile compared to other parts of Bangladesh due to water exchange by tidal action. An special type of aquatic floating grass (*Hygroryza aristata*) is cultivated in these inundated low-lying lands after rice production and scattered on the floating bed (made by water hyacinth) as composed fertilizer for producing vegetables and spice crop seedlings (greens, gourd, pumpking, bitter gourd, snake gourd, cucumber, tomato, bean, brinjal, turnip, radish, cabbage, cauliflower, ladies finger, spinach etc). Many species of fishes (*Ctenopharyngodon idella, Mylopharyngodon pisceus, Puntius gonionotus, Cyprinus Carpio, Cyprinus Carpio var. specularis, Cirrhinus cirrhosis, Oreochromis niloticusetc*) prefer this *Hygroryza aristata* floating grass as their food directly and indirectly.

Hygroryza aristata is a glabrous floating grass, having spongy stem with feathery whorled roots at the nodes and naturally long, good hiding places of insects, crustaceans, zooplankton and mollusks;and provides food for many species. It grows well in the sunny place of low-lying lands, canals and beels. It contains 7.92% protein (Rastogi and Mehrotra, 1990) on moisture content and growth is very fast. It increases with increasing water level during the season and after harvesting, it naturally grows from their root system. Ogello *et al.* (2014) reported that several species of aquatic plants could be potential sources of fish meal replacers in aquaculture. As the global fishmeal price has increased more than two fold in recent years therefore, we used this *Hygroryza aristata* floating grass as fish feed directly as natural condition in the same ecosystem for reducing fish production cost that was a new initiative in the fisheries sector of Bangladesh as well as in the word.

7. **Sub-project goal:**

   Development of sustainable aquaculture technique in inundated low-lying lands using floating grass, *Hygroryza aristata* as fish feed for reducing fish production cost.

8. **Sub-project objective (s):**

   i. To utilize the submerged low-lying agriculture land and tidal water for sustainable aquaculture system;

   ii. To utilize *Hygroryza aristata* floating grass as fish feed for reducing fish production cost;

   iii. To determine the proximate composition of *Hygroryza aristata* floating grass and fish in relation to growth performance; and

   iv. To examine the biological, economical and environmental advantages achieved through new interventions proposed for the aquaculture systems.

9. **Implementing location (s):** Inundated low-lying agriculture land of *Banaripara* under Barishal district.

10. **Methodology in brief:**

10.1. Experimental design

Three treatments (T_1, T_2 & T_3) were set-up in the inundated low-lying agriculture land covering an area of 30 decimal for each treatment where two sides of the land were closed by dyke (locally called kandi) and the rest two sides were open to exchange water (average 0.7m water level up-down two times daily) due to action of tide. These open sides of all treatments were closed combined with bamboo split made mats and small mesh size (0.5cm) knotless cott net so that tidal water can pass through the mats but not fish. Approximately 2.5–3.0m width and 0.5-0.6m depth lateral canal were created at the beginning of the research work in each treatment to keep water at ebb tide in winter season. Large size fingerlings of test fish species such as Grass Carp (*Ctenopharyngodon idella*), Black carp (*Mylopharyngodon pisceus*), Common carp (*Cyprinus Carpio*) and Tilapia (*Oreochromis niloticus*) were stocked in July 2017 at the rate of 50 fishes per decimal (12350 fish ha^{-1}) in all treatments. During stocking of fish, initial weight of 10% fish of each species of each treatment were measured by using a portable weight balance (model: M-ACS015G/C) for keeping record separately. *Hygroryza aristata* floating grass was planted on bottom soil approximately 80% of total area in treatment-1 (T_1) to use it as ready feed for fish. This floating grass was also planted elsewhere in another 35 decimal low-lying agriculture land for growing naturally and providing it in treatment-2 (T_2) as fish feed after collecting from this cultivated land. Commercial floating fish feed was applied for fishes in treatment 3 (T_3) at the rate of 8% of the body weight of fish for 1^{st} two month and then reduced to 6% of the body weight of fish for 2^{nd} two months and finally reduce to 4% of the body weights of fish were maintained for rest of the culture period.

Project activity

Plate1: *Hygroryza baristata* floating grass was planted before fish stocking

Plate2: Preparation of bamboo split made mats and net for setting

Plate 3: Combined set of bamboo splits made mats and net

Plate 4: Project site including signboard

Plate 5: Supply of fingerlings

Plate 6: Stocking of fingerlings

Plate 7: Supply of *Hygroryza aristata* floating grass as fish feed in T_2

Plate 8: Supply of commercial fish feed in T_3

Plate 9: Sampling of fish and growth monitoring

Plate 10: Measurement of weight and keeping record

10.2. *Hygroryza aristata* floating grass Plantation

All types of unwanted aquatic weeds wereremoved from all the experimental plots and cleaned at the beginning of the work. Then, *Hygroryza aristata* floating grass was planted approximately 80% of the total area in T_1 on bottom soil including the deeper channel of land. During plantation, 0.5-1.0 feet long anterior portion of *Hygroryza aristata* floating grass was used as seedlings and planted 3-4 pieces together while column and row were maintained like paddy plantation; column to column and row to row distance was 20cm and 25cm respectively. Another 35decimal of low-lying agriculture land adjacent to the experimental area was also used for plantation of *Hygroryza aristata* floating grass to supply it as feed for the fishes in T_2 where column and row were maintained as in T_1. After stocking of fish, *Hygroryza aristata* floating grass was collected on boat from this low-lying cultivated land and carried to the experimental plot and supply as fish feed in T_2, but this *Hygroryza aristata* floating grass was growing naturally in T_1 and stocked fishes were fed them as ready feed throughout the study period.

10.3. Fish stocking

Large size fingerlings of fish species such as Grass Carp (*Ctenopharyngodon idella*), Black carp (*Mylopharyngodon pisceus*), Common carp (*Cyprinus Carpio*) and Tilapia (*Oreochromis niloticus*) were stocked in July 2017at the rate of 50 fishes (Grass Carp 30, Black carp 5, Common carp 5, and Tilapia 10) per decimal in all treatments after three months of *H. aristata* floating grass plantation. During stocking of fish, initial weight of 10% fish of each species of each treatment were measured by using a portable weighing balance (model: M-ACS015G/C) for keeping record independently.

10.4. Feed supply

Commercial floating fish feed (Paragoan Fish Feed Ltd.) was applied twice in a day between 900 and 1000 hrs in first time and 1600 to 1700 hrs in second time only in T_3. Commercial floating fish feed was applied at the rate of 8 % of the body weight of fish for first two months then reduced to 6% of the body weight of fish for 2nd two months and thereafter reduce to 4% of the body weight of fish were maintained for the rest of the culture period. No feed or fertilizer was applied in T_1 and T_2 throughout the study period.

Hygroryza aristata floating grass supply as fish feed in T_2

Commercial floating feed supply in T_3

10.5. Study of water quality parameters

Physico-chemical parameters such as water Temperature (^{o}c), Transparency (cm), Dissolved oxygen content (mgL^{-1}), pH and Salinity (‰) were recorded during stocking of fish, moreover parameters were measured fortnightly from at least three different spots of each treatment using thermometer, secchi disk, portable DO meter (DO-5509, AF.11581, Taiwan), digital pH meter (pHep, HANNA Instruments, Romania) and digital refractometer (Brix HI 96801). Water samples were collected in 250ml plastic bottles from three different spots of each treatment to determine total Alkalinity, Ammonia, Nitrate-N and Phosphate-P in the laboratory of the Faculty of Fisheries, Patuakhali Science and Technology University. Ammonia, Nitrate-N and Phosphate-P were determined by using spectrophotometer (DR 1900, HACH, USA) and total Alkalinity was measured by titrimetric method using 0.02N H_2SO_4 titrant and methyl orange indictor.

10.6. Fish sampling and data collection

Fish sampling was done using cast net at monthly intervals to monitor the growth and measured weight in all treatments. Weights were recorded to measure the growth performance and to adjust feeding ration in T_3 in each month.

10.7. Fish harvesting and data collection

All the fish were harvested from all the treatments after 1 year of rearing. The harvested fishes were counted and weighed individually at least 10% fish of each species of each treatment by using a portable weight balance and recorded separately to estimate the final weight, weight gain, % weight gain, production, growth and specific growth rate (SGR), survival rate, and FCR (Food Conversion Ratio in T_3) respectively as follows:

- ✓ Specific growth rate (SGR) = [In (final weight) – In (initial weight)]/culture period (days) ×100;
- ✓ Food conversion ratio (FCR) was calculated as: FCR = Dry weight (g) of feed supplied/Live weight (g) of fish gained according to Ricker, 1975; and
- ✓ Survival rate was estimated as survival Rate (%) = [No. of harvested fishes/Initial no. of stocked fish] ×100.

10.8. Proximate composition analysis

Proximate composition of *Hygroryza aristata* floating grass, supplied commercial floating fish feed and grass Carp were analyzed in the Fish Nutrition Laboratory under the Department of Aquaculture, Bangladesh Agricultural University, Mymensingh following the analytical methods of AOAC (2000). Fish fillets of grass Carp (three samples in each treatment) were collected, then separated and were stored at -20^{o}C temperature after proper labeling and finally brought to the laboratory for analysis. Proximate composition of *Hygroryza aristata* floating grass was analyzed in dried and wet condition. Grass samples were collected, sun dried for 10-12 days, packaged in polyethylene paper and brought to the Fish Nutrition Laboratory under the Department of Aquaculture, Bangladesh Agricultural University, Mymensingh for proximate analysis. Simultaneously, grass samples were brought to the laboratory in wet condition and kept under shadow for 1-2 days to be air dried at room temperature, finally packaged in polyethylene paper and preserved in the laboratory for analysis.

10.9. Data analysis

The data of water quality parameters, growth rate, survival rate, production, SGR and FCR were expressed as mean ± standard deviation (SD) and were analyzed by one-way analysis of variance (ANOVA), followed by testing of pair-wise differences using Duncan's Multiple Range Test. Significance was assigned at the 5% level (P>0.05). All statistical analysis were done using SPSS (Statistical Package for Social Science) version 20. Moreover, a tabular financial analysis was done to assess the economic viability according to Shang, (1990).

11. Results and discussion

11.1. Water quality parameter

Physico-chemical parameters of water quality such as water Temperature (^{0}C), Transparency (cm), Dissolved oxygen content (mgL^{-1}), pH, Salinity (‰), Nitrate-N and Phosphate-P, total Alkalinity (mgL^{-1}) and Ammonia (mgL^{-1}) are presented in Table 1. The mean temperatures were recorded between 18.45±0.13^{o}C and 32.33±0.59^{o}C among the treatments while the highest and lowest temperatures were observed in T_1 in the month of June and January respectively. Monthly variation of water temperature (^{o}C) in three different treatments during the study period shown in Figure 1. Transparency was also measured from three different treatments while the highest value was recorded 72.25±2.22cm and the lowest value was found 23.25±1.26cm in T_3 among the treatments. The monthly variation of water transparency (cm) in three different treatments shown in Figure 2. Dissolved oxygen content was found to range between 5.14±0.07 and 5.87±0.12 mgL^{-1}. The monthly variation of dissolved oxygen content is shown in figure 3. The pH was calculated 6.94±0.05 to 7.23±0.07 and monthly variation of pH in three different treatments during the study period shown in figure 4. The highest value of dissolved oxygen content was recorded in T_1 in month of July and the lowest was found in T_2 in month of September while the highest pH was calculated in the month of November and March in T_3 and the lowest was recorded in T_2 and T_3 in the month of February and December. Total Alkalinity was measured between

50.75±10.31 and 153.50±9.04 mgL^{-1} while the monthly variation of this parameter in three different treatments is shown in figure 6. Nitrate-N was observed between 0.007±0.003 mgL^{-1} and 0.012±0.003 mgL^{-1} and Phosphate-P was recorded between 0.19±0.08 $mgL^{-1}$and 1.82±0.28 mgL^{-1} and monthly variation of these two parameters in three different treatments are shown as figure 7 and 8. Ammonia was found very low amount and this was found below the range of spectrophotometer reading

Table 1: Treatment wise water quality parameters (mean±SD, n=4) of the experimental water area

Parameters	Treatment	July	August	September	October	November	December	January	February	March	April	May	June
Temperature (^0C)	Air tem.	31.0	32.5	30.7	28.5	26.3	19.4	12.4	21.2	26.7	33.5	34.4	36.3
	T_1	29.83±0.17	29.50±0.41	28.50±0.41	27.76±0.21	25.22±0.23	21.15±0.26	18.45±0.13	23.25±0.19	24.20±0.18	30.05±0.31	30.15±0.26	32.33±0.59
	T_2	29.50±0.41	29.35±0.13	28.30±0.22	27.41±0.20	25.31±0.19	21.28±0.22	19.80±0.42	23.08±0.17	24.18±0.28	30.18±0.28	30.60±0.18	32.30±0.53
	T_3	29.49±0.23	29.35±0.26	28.25±0.21	27.38±0.30	25.23±0.17	21.20±0.16	18.98±0.13	22.98±0.17	24.05±0.13	30.10±0.18	31.18±0.28	32.20±0.29
Transparency (cm)	T_1	68.50±3.11	52.25±2.22[a]	51.50±1.29[a]	45.75±2.22[a]	43.75±1.71[a]	29.00±1.83[a]	29.75±1.71	30.00±1.41	28.25±1.26	25.00±1.41	27.00±0.82[a]	23.50±1.29
	T_2	69.50±2.65	44.75±3.40	45.75±0.96[b]	42.50±2.08[ab]	38.25±1.26	27.00±0.82[ab]	30.75±0.96	31.75±1.50	31.50±1.29[a]	25.00±0.82	25.50±1.92[ab]	26.50±1.29[a]
	T_3	72.25±2.22	44.50±1.29	38.75±0.96[c]	40.50±2.08	39.00±1.83	26.25±1.50	28.50±1.29	32.00±1.41	32.00±1.83[a]	23.25±1.26	23.75±1.71	24.00±0.82
DO (MgL^{-1})	T_1	5.87±0.12[a]	5.53±0.12	5.41±0.21	5.46±0.11	5.28±0.06	5.64±0.14[a]	5.30±0.10	5.21±0.19	5.37±0.13	5.71±0.09	5.19±0.09	5.65±0.15[a]
	T_2	5.56±0.12	5.53±0.16	5.14±0.07	5.29±0.13	5.30±0.17	5.53±0.15[ab]	5.46±0.28	5.32±0.30	5.54±0.26[a]	5.59±0.25	5.54±0.14	5.43±0.15[ab]
	T_3	5.46±0.17	5.49±0.15	5.29±0.19	5.47±0.18	5.26±0.22	5.38±0.13	5.46±0.24	5.33±0.34	5.46±0.21[a]	5.54±0.22	5.62±0.20	5.39±0.15
pH	T_1	6.94±0.23	7.10±0.13[a]	7.13±0.10	7.01±0.10	7.04±0.18	7.01±0.06	6.99±0.08	6.94±0.06	7.07±0.10	6.96±0.05	7.16±0.12	7.18±0.14
	T_2	7.21±0.17	7.02±0.05[ab]	7.12±0.09	7.07±0.06	7.06±0.06	6.93±0.05	7.08±0.08	6.94±0.05	6.95±0.07	6.96±0.11	7.11±0.08	7.12±0.11
	T_3	7.14±0.13	6.94±0.06	7.10±0.04	7.13±0.06	7.23±0.07	6.94±0.05	6.97±0.06	6.95±0.09	7.23±0.07[a]	6.94±0.07	7.06±0.06	7.02±0.07
Alkalinity (MgL^{-1})	T_1	115.75±5.91	148.00±6.33	119.50±5.51	107.50±5.80	104.00±8.08	96.00±7.26	82.75±4.03	91.25±4.65	83.00±6.78	55.25±6.02	60.25±12.45	131.75±10.49
	T_2	123.25±10.44	151.75±7.89	122.75±6.90	113.00±3.92	102.25±6.95	96.50±6.46	79.00±4.40	91.00±3.74	74.25±5.62	59.50±10.97	53.75±6.13	131.75±8.46
	T_3	125.00±6.58	153.50±9.04	125.00±5.35	121.25±2.99[a]	107.00±3.16	100.00±5.07	77.50±3.87	90.25±4.57	93.25±5.85[a]	56.25±8.42	50.75±10.31	125.25±7.04
Nitrate-N (MgL^{-1})	T_1	0.008±0.002	0.009±0.002	0.011±0.002	0.009±0.002	0.010±0.002	0.009±0.003	0.010±0.001	0.010±0.002	0.012±0.002	0.009±0.003	0.012±0.002	0.009±0.002
	T_2	0.008±0.001	0.009±0.001	0.010±0.003	0.012±0.001	0.010±0.002	0.010±0.001	0.010±0.002	0.009±0.001	0.007±0.003	0.008±0.003	0.012±0.002	0.010±0.002
	T_3	0.009±0.001	0.008±0.002	0.012±0.002	0.010±0.002	0.010±0.002	0.010±0.002	0.010±0.002	0.010±0.001	0.007±0.003	0.011±0.003	0.009±0.003	0.010±0.002
Phosphate-P (MgL^{-1})	T_1	0.47±0.04	0.49±0.06	0.47±0.07	0.39±0.05	0.29±0.04	0.31±0.06	0.34±0.04	0.43±0.04	0.60±0.12[a]	0.98±0.08[a]	0.82±0.13[a]	0.46±0.06[a]
	T_2	0.47±0.03	0.52±0.04	0.49±0.06	0.39±0.04	0.31±0.04	0.31±0.03	0.36±0.04	0.41±0.03	0.19±0.08	0.69±0.10	0.61±0.10	0.36±0.06[ab]
	T_3	0.46±0.02	0.45±0.03	0.49±0.03	0.38±0.03	0.27±0.02	0.31±0.03	0.37±0.04	0.43±0.04	0.20±0.09	0.82±0.28[b]	0.78±0.12[ab]	0.35±0.06
Salinity (‰)	T_1	0.10±0.00	0.10±0.00	0.10±0.00	0.10±0.00	0.10±0.00	0.20±0.00	0.20±0.00	0.20±0.00	0.10±0.00	0.10±0.00	0.10±0.00	0.10±0.00
	T_2	0.10±0.00	0.10±0.00	0.10±0.00	0.10±0.00	0.10±0.00	0.20±0.00	0.20±0.00	0.20±0.00	0.10±0.00	0.10±0.00	0.10±0.00	0.10±0.00
	T_3	0.10±0.00	0.10±0.00	0.10±0.00	0.10±0.00	0.10±0.00	0.20±0.00	0.20±0.00	0.20±0.00	0.10±0.00	0.10±0.00	0.10±0.00	0.10±0.00

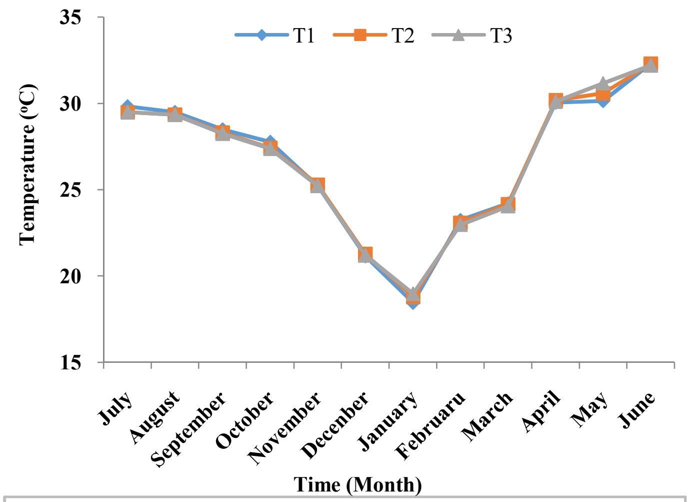

Figure 1. Monthly variation of water temperature (ºc) in different treatments

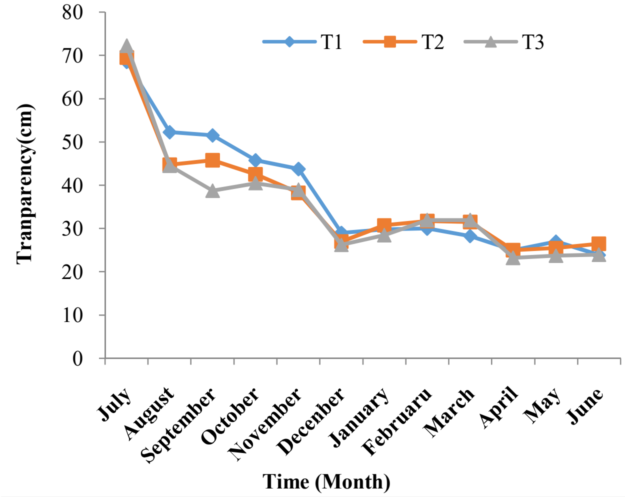

Figure 2. Monthly variation of water transparency (cm) in different treatments

among the treatments during the study period. The most important parameter of water salinity in coastal region which was recorded 1‰ in the month of March to November and 2 ‰ in the month of December to February in all treatments during the study period (Figure 5). The mean Nitrate-N level was recorded highest in T_1 and T_2 in the month of May and in T_3 in the month of September while the lowest value was found in T_2 and T_3 in the month of March and June respectively. The amount of Phosphate-P was found highest in T_3 in April and lowest in T_2 in March but total Alkalinity was observed highest and

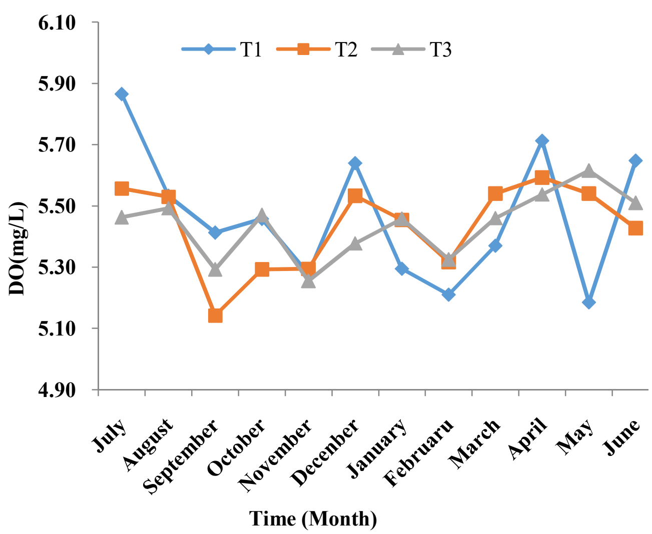

Figure 3. Monthly variation of DO (mgL^{-1}) in different treatments

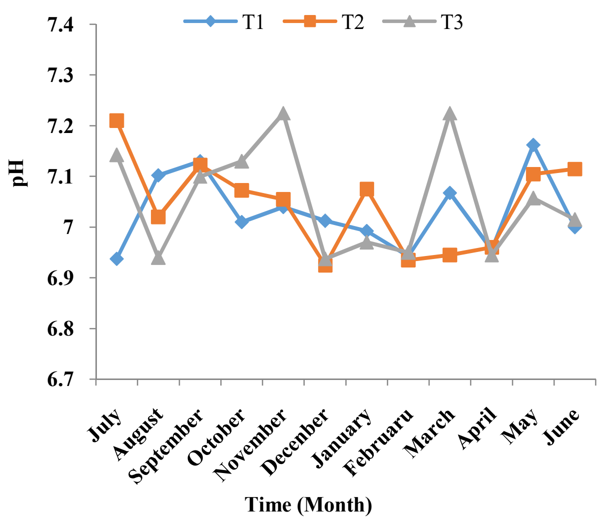

Figure 4. Monthly variation of pH in different treatments

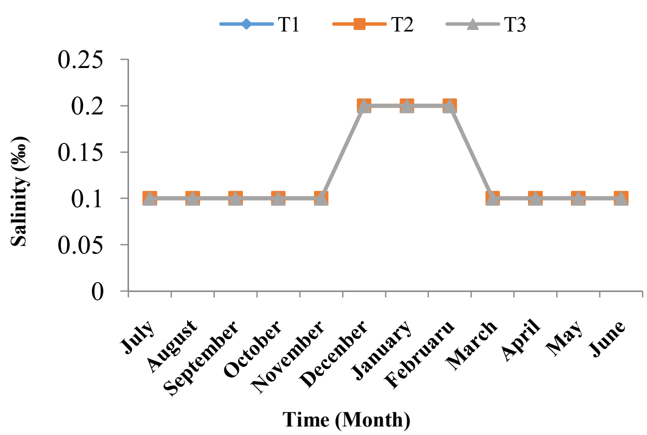

Figure 5. Monthly variation of Salinity (‰) in different treatments

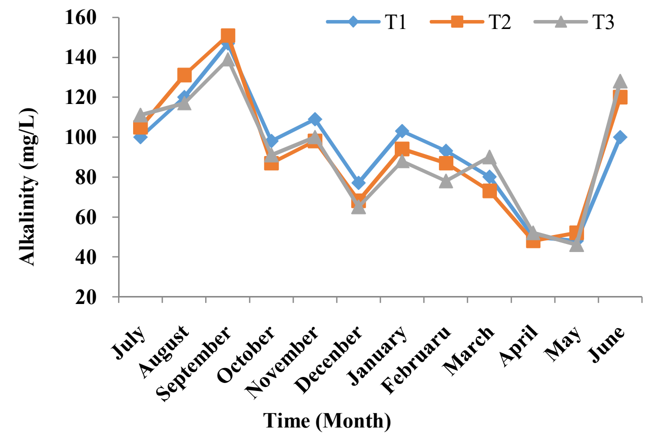

Figure 6. Monthly variation of Alkalinity (mgL^{-1}) in different treatments

The amount of dissolved oxygen content, total alkalinity and value of pH were found very suitable range and were more or less similar throughout the study period owing to daily water exchanged by tidal action in the coastal region. This is to be noted that the lowest water temperature was recorded 18.45±0.13°C in January while the air temperature was found 12.4°C that was big difference. But during this time, increasing growth of fish was recorded due to higher water temperature in the experimental site that was not possible elsewhere in Bangladesh of aquaculture system.

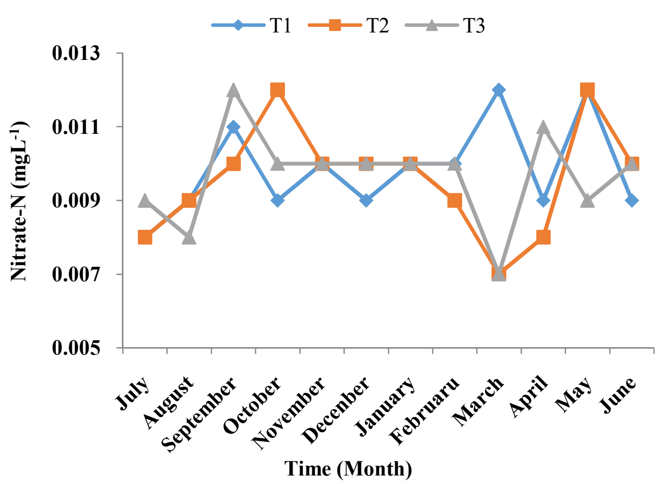

Figure 7. Monthly variation of Nitrate-N (mgL^{-1}) in different treatments

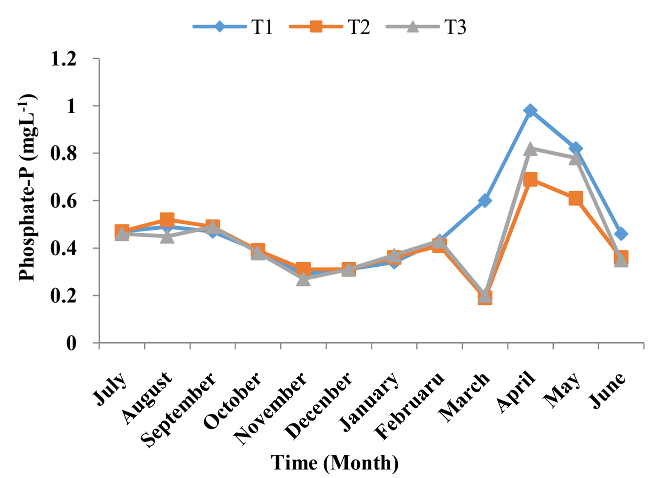

Figure 8. Monthly variation of Phosphate-P (mgL^{-1}) in different treatments

Moreover, the findings of physico-chemical parameters of this study were found suitable for Carp culture and supported by many authors which were observed during their experiments in different times of Carp culture e.g. production and growth performances of Carps in different stocking densities of polyculture (Haque *et al.,* 2015); growth performance of Indian major Carps on different feed regimes with cost-benefit analysis (Chowdhury and Hasan*,* 2015); effects of inorganic fertilizers on the growth and production performance of exotic Carps in polyculture system (Hossain *et al.,* 2008); the effects of grass Carp on aquatic plants, plankton and benthos in ponds (Kirkagac and Demir, 2004) and impacts of Thai silver barb *(Puntius gonionotus* Bleeker) inclusion in the polyculture of Carps (Haque *et al.*, 1998). Higher temperature contributed higher growth rate of Common carp in the tropical region compared with central Europe (Steffens and Wirth, 2007). Moreover, all the water quality parameters were more or less similar in three different treatments, although two different feed items such as commercial floating fish feed and *Hygroryza aristata* floating grass were supplied as fish feed in the experimental sites.

11.2. Growth performance

Details of initial weight, final weight, weight gain, % weight gain, survival rate, FCR, SGR, and production performance of all cultured species in three different treatments are shown in Table 2. The mean initial weights of cultured fish species were recorded with the highest in case of Black carp (53.00±3.22g in T_1; 51.40±2.70g in T_2 and 53.00±2.92g in T_3) followed by Grass Carp (40.10±4.33g in T_1; 40.35±4.20g in T_2 and 40.65±4.38g in T_3), Common carp (18.60±2.30g in T_1; 19.80±1.92g in T_2 and 19.20±1.48g in T_3), and Tilapia (11.60±1.14g in T_1; 10.80±0.84g in T_2 and 10.60±1.52g in T_3). The final weight were recorded with the highest in case of Grass Carp (1034.75±52.59g in T_1, 951.95±58.89g in T_2 and 898.25±71.10g in T_3) followed by Common carp (1033.60±43.15g in T_1, 1023.40±35.65g in T_2 and 948.80±39.27g in T_3), Tilapia (543.20±44.87g in T_1, 490.20±68.15g in T_2 and 896.40±45.32g in T_3) and Black carp (462.60±37.91g in T_1, 439.80±50.38g in T_2 and 450.60±53.54g in T_3) respectively.

The % weight gains were recorded with the highest in Tilapia (8500.26±1369.73 in T_3) followed by Common carp (highest 5522.79±577.91in T_1), Grass Carp (highest 2502.06±247.52in T_1) and Black carp (highest 775.28±84.80 in T_1) that were significantly different ($P<0.05$) among the treatments.

The gross productions were recorded with the highest 9060.70 kgha^{-1} in T_1 followed by 8469.70kgha^{-1} in T_3 and 8001.23 kgha^{-1} in T_2 during the study period (Table 2). Specific growth rate (SGR % day-1) were found with the highest 1.31±0.05 in Tilapia in T_3 while it was recorded 1.13±0.03 and 1.12±0.05 in T_1 and T_2 respectively during the study period. Specific growth rate of Common carp were recorded 1.18±0.03, 1.16±0.02 and 1.15±0.02 whereas it was found 0.96±0.03, 0.93±0.03 and 0.91±0.03 in grass Carp in T_1, T_2 and T_3 respectively during the study period.

The mean highest weight gain of cultured species was observed 1017.00±41.09g in case of Common carp in T_1 while it was found 998.25±31.85g in T_2 and 929.60±38.29g in T_3 (Table 2). The highest weight gain of Grass Carp was recorded 994.65±50.98g in T_1 followed by 911.60±58.81g in T_2 and 857.60±68.77g in T_3. The weight gain of Back Carp and Tilapia were recorded 409.60±37.43g, 388.40±50.16g, 397.60±51.83g and 531.60±44.62g, 479.40±68.46g and 885.80±45.70g in T_1, T_2 and T_3 respectively during the study period.

The highest survival rate was recorded in Black carp (85.14%) in T_2 followed by Grass Carp (84.76%) in T_1, Tilapia (84.29%) and Common carp (81.14%) in T_3 during the study period (Table 2 and Figure 13).

The highest production performance was observed in Grass Carp 6499.12kgha^{-1} in T_1 followed by 5609.57kgha^{-1} in T_2 and 5217.06 kgha^{-1} in T_3 while the contribution of this species to the total production was calculated 71.73%, 70.11% and 61.60% in T_1, T_2 and T_3 respectively (Table 2 and Figure 15).

Fish production performance

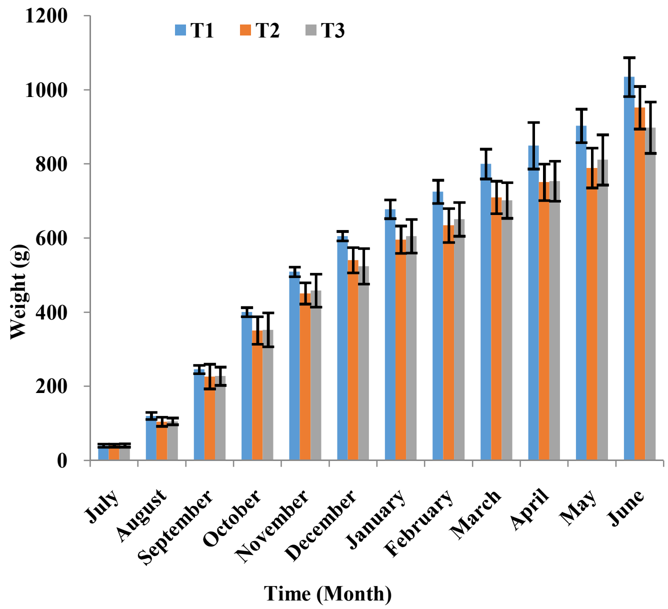

Figure 9. Growth performance of Grass carp in different treatments

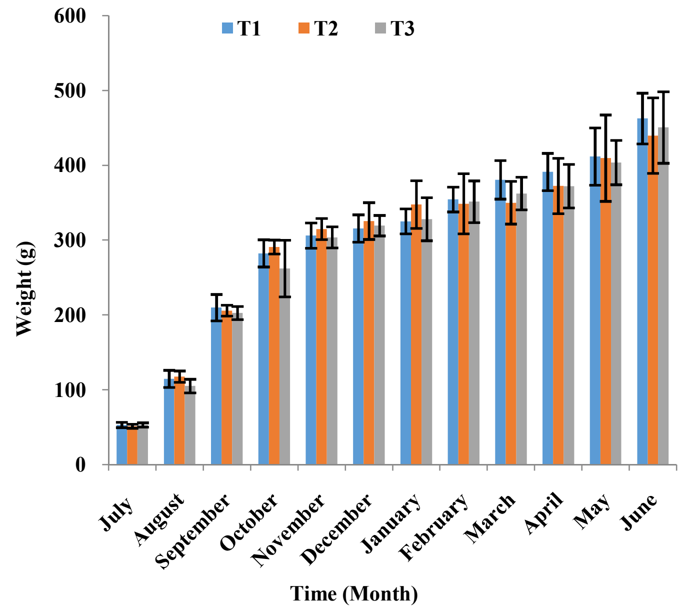

Figure 10. Growth performance of Black carp in different treatments

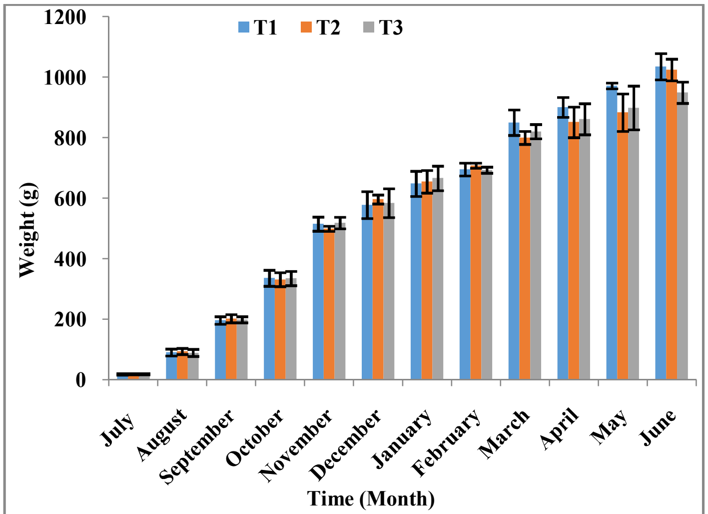

Figure 11. Growth performance of Common carp in diffrent treatments

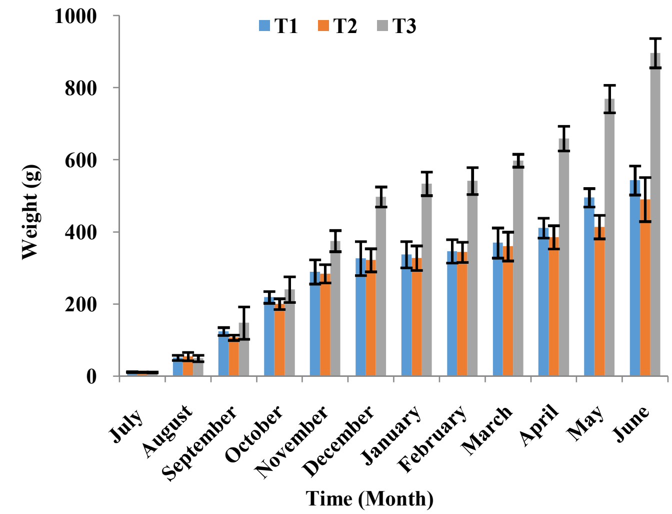

Figure 12. Growth of performance of tilapia in different treatments

The production performance of Black carp were found 470.11 kg ha^{-1}, 462.46 kg ha^{-1} and 435.65 kg ha^{-1} while the contribution of this species to the total production were calculated 5.19%, 5.78% and 5.14% in T_1, T_2 and T_3 respectively (Figure 15). The production performance of Common carp and Tilapia were calculated 999.69 kg ha^{-1}, 941.71 kg ha^{-1}, 931.57 kg ha^{-1} and 1061.7 kg ha^{-1}, 947.29 kg ha^{-1} and 1844.11 kg ha^{-1} in T_1, T_2 and T_3 respectively during the study period while the contribution of these two species to the total production was calculated 11.11 %, 12.01 %, 11.23 % and 11.97 %, 12.11 % and 22.03 % in T_1, T_2 and T_3 respectively. The total gross production performance was measured highest 9060.757 kg ha^{-1} in T_1 followed by 8469.7 kg ha^{-1} in T_3 and 8001.23 kg ha^{-1} in T_2 during the study period (Table 2 and Figure 15).

11.2.1 Grass Carp (*Ctenopharyngodon idella*)

The production performance of Grass Carp was observed 6499.12 kg ha^{-1}, 5609.57 kg ha^{-1} and 5217.06 kg ha^{-1} while its contribution to the total production was calculated 71.73%, 70.11% and 61.60% in T_1, T_2 and T_3 respectively (Figure 9) were satisfactory. *Hygroryza aristata* floating grass is produced in the coastal region especially in the experimental site where it was mainly used as Grass Carp fish feed directly in this experiment to reduce the fish production cost. Grass Carp has been introduced into more than 50 countries for food fish culture and aquatic vegetation management which is effective to control many species of algae and submerged aquatic vegetation (SRAC publication, 2002).

Table 2: Production performance of cultured fish species (mean±SD, n=20 for grass Carp and n=5 for other species) in different treatments

Treatment	Species	Weight (g)			SGR (% day^{-1})	% Weight Gain	Survival Rate (%)	Production (kg)/ha.		Production (kg ha^{-1} $year^{-1}$)		FCR	Percent contribution to the yield (%)
		Initial weight (g)	Final weight (g)	Weight Gain (g)				Gross	Net	Gross	Net		
T_1	Grass Carp	40.10±4.33	1034.75±52.59^{a}	994.65±50.98^{a}	0.96±0.03^{a}	2502.06±247.52^{a}	84.76	6499.12	6247.25	9060.70	8724.89	-	71.73
	Black carp	53.00±3.52	462.60±37.91	409.60±37.43	0.64±0.03	775.28±84.80	82.29	470.11	416.25				5.19
	Common carp	18.60±2.30	1033.60±43.15^{a}	1017.00±41.09^{a}	1.18±0.03^{a}	5522.79±577.91^{a}	78.86	1006.61	999.69				11.11
	Tilapia	11.60±1.14	543.20±44.87	531.60±44.62	1.13±0.03	4613.14±543.03	80.86	1084.86	1061.7				11.97
T_2	Grass Carp	40.35±4.20	951.95±58.89^{b}	911.60±58.81^{b}	0.93±0.03^{b}	2282.22±275.19^{b}	79.52	5609.57	5371.8	8001.23	7669.21	-	70.11
	Black carp	51.40±2.70	439.80±50.38	388.40±50.16	0.63±0.04	756.96±98.97	85.14	462.46	408.41				5.78
	Common carp	19.80±1.92	1023.40±35.65^{a}	1003.25±31.85^{a}	1.16±0.02^{ab}	5071.73±402.23^{ab}	76.00	960.56	941.71				12.01
	Tilapia	10.80±0.84	490.20±68.15	479.40±68.46	1.12±0.05	4475.97±863.49	80.00	968.64	947.29				12.11
T_3	Grass Carp	40.65±4.38	898.25±71.10^{c}	857.60±68.77^{c}	0.91±0.03^{c}	1920.51±203.51^{c}	78.38	5217.06	4980.97	8469.70	8141.06	1.62	61.60
	Black carp	53.00±2.92	450.60±53.54	397.60±51.83	0.63±0.03	749.60±84.59	78.29	435.65	384.41				5.14
	Common carp	19.20±1.48	948.80±39.27	929.60±38.29	1.15±0.02^{c}	4856.79±279.92^{c}	81.14	950.81	931.57				11.23
	Tilapia	10.60±1.52	896.40±45.32^{a}	885.80±45.70^{a}	1.31±0.05^{a}	8500.26±1369.73^{a}	84.29	1866.18	1844.11				22.03

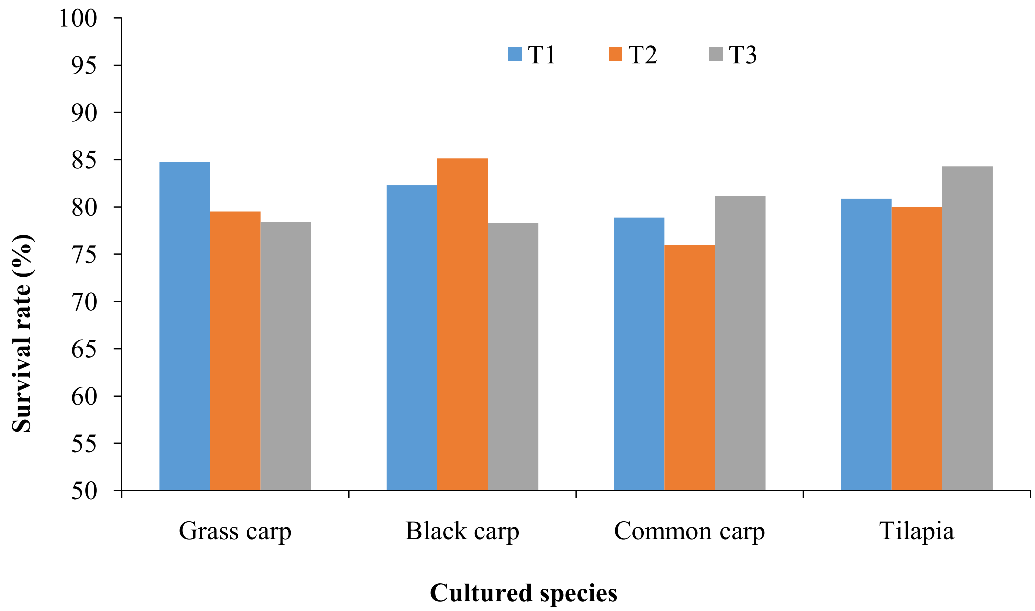

Figure 13. Survival rate (%) of different fish species in three different treatments

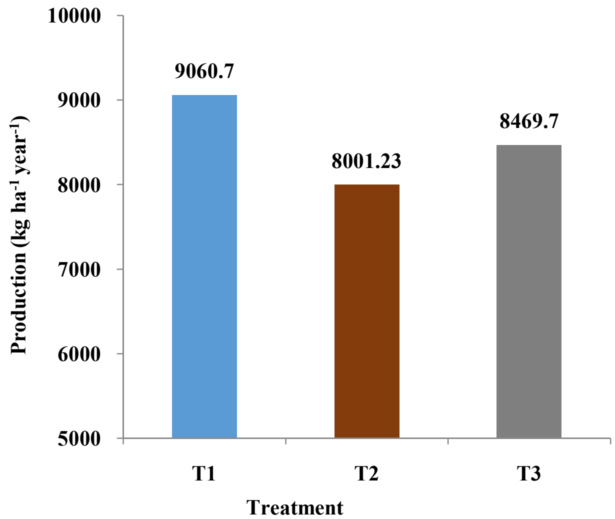

Figure 14. Production performance (Kg ha^{-1}) in three different treatments

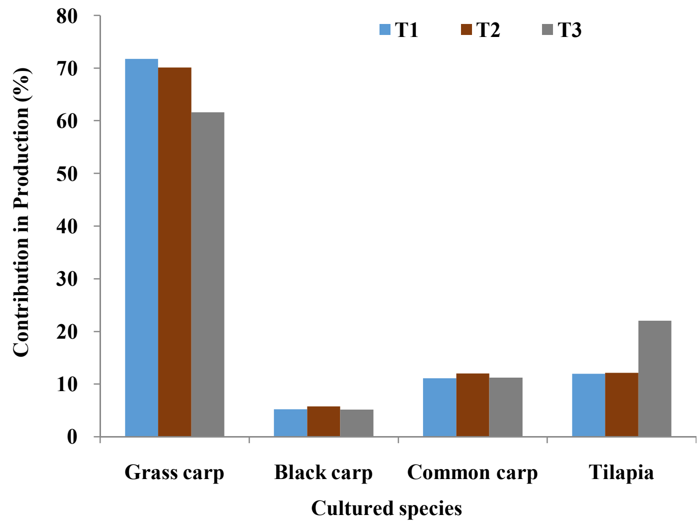

Figure 15. Species contribution (%) in production performance in three dittrent treatments

More than 50 genera of food items, including aquatic macrophytes, algae, invertebrates and vertebrates especially hydrilla and pond weeds (*Potamogeton* spp.) were the most common food items to be eaten by grass Carp (Cross, 1969; Pine and Anderson, 1991; Dibble and Kovalenko, 2009). The amount of aquatic plants consumed by Grass Carp and its selectivity depends on many factors, but particularly on Grass Carp stocking density, Grass Carp age, temperature conditions, the length of culture period, and on the quantity and quality of food present are also very important. In temperate climates Grass Carp prefer submerged and floating aquatic plants, although it will eat almost any type of vegetation when its preferred food is not available (Stroganov, 1963; Fischer, 1968; Sutton, 1977; Lembi *et al.*, 1978). In this study, Grass Carp were stocked to determine the growth performance depending on *Hygroryza aristata* floating grass used as feed and utilization of submerged unused agriculture land; but others fish such as Back Carp, Common carp and Tilapia were stocked to use the by-products of Grass Carp feeds' settle on the bottom, various types of insects, zooplankton and mollusk that survive on this floating grass and bottom mud; and to maintain the environmental condition suitable for aquaculture. There is an important advantageous factor existence here that daily exchange of aquaculture water by tidal action through bamboo splits made mats facilitate to maintain the good quality of water with friendly environment in aquaculture system. The average final weight of Grass Carp were found 1034.75±52.59g in T_1 and951.95±58.89gin $T_2$by feeding *Hygroryza aristata* floating grass directly that was significantly different (P<0.05) from T_3 (898.25±71.10)feed with commercial floating fish feed. This finding indicates that *Hygroryza aristata* floating grass was very efficient for higher growth of Grass Carp. Kırkağaç and Demir (2004) investigated the effects of the Grass Carp (*Ctenopharyngodon idella*) on aquatic plant biomass, water quality, phytoplankton, chlorophyll-*a*, zooplankton and benthic fauna in earthen ponds and observed that plant biomass increased 1.4 times in the pond without Grass Carp but was decreased 2.5 times in the ponds stocked with 200 and 400 Grass Carp per ha and decreased 4 times when stocked with 600 Grass Carp per ha and survival rate was 100%. Pipalova, (2006) reported that intensity of aquatic macrophyte control using Grass Carp depend on many factors i.e. stocking density, Grass Carp age (size), duration of their stocking, temperature conditions, aquatic macrophyte species present and type of water reservoir. During our study, we found the range of water temperature between 18°C to 29°c that are similar to many authors such as Krupauer (1989) described that the optimum water temperature for food consumption by the Grass Carp was 20 to 28°C. Stroganov (1963) and Opuszynski

(1972) stated that the optimum water temperature: 21 to 26°C and 25 to 28°C respectively and at 20°C daily food intake by Grass Carp was 50% of its body weight, whereas at 22°C the consumption increased up to 120% of body weight. A gradual decrease of water temperature (even below 15°C) increased feeding selectivity of Grass Carp but its food consumption did not decrease (Krupauer, 1989).

11.2.2 Black carp (*Mylopharyngodon pisceus*)

The final weights of Black carp were recorded as 409.60±37.43g, 388.40±50.16g and 397.60±51.83g in T_1, T_2 and T_3 (Figure 10) those were not significantly different (P>0.05) among the treatments. Compared to other cultured species, growth of Black carp was very low which could be due to higher stocking density of the species resulted insuffient intake of preferred natural feed in the experimental sites. Otherwise, it might be due to the effect of change in water level caused by daily tidal action. Black carp is a bottom dwelling fish known as snail Carp. It prefers channels and associated floodplain lakes and return to waters of lowland rivers. According to AIS (2009) report, Black carp desire native mollusk populations as their main diet at maturity consists primarily of Snails, Mussels, and Clams, and it is also known to scavenge for fish eggs, aquatic insects, and benthic crustaceans. Nico*et al.* (2005) reported that the primary habitat of the Black carp includes river, channels and floodplain lakes of temperate, lowland rivers that support an abundance of mollusks. Moreover, many authors reported that the growth rate of Black carp is very high and their main food is snails (Halwart, 1994; Ben-Ami and Heller, 2001; Nico*et al.,* 2005; Hung*et al.,* 2013). According to AIS (2009), the young Black carp feed on zooplankton and fingerlings and as adults their feeding habits change to mollusks, crustaceans, aquatic insects, and fish eggs, a 4-year-old Black carp is able to eat 3 to 4 pounds of mussels per day. Black carps have powerful teeth that facilitate them to crush mussel shells, eat the soft parts, and spit the shell out. Nico *et al.* (2005) informed that larvae and small juveniles of Black carp feed almost entirely on zooplankton and aquatic insects while larger juveniles and adults feed mainly on mollusks. Recent studies and profitable use of Black carp have found this species have one of the highest potentials for biological control of snails (Venable *et al.,* 2000; Ledford and Kelly 2006; Wui and Engle 2007). Hodgins *et al.* (2014) estimated the specific growth rate of Black carp 0.16 to 0.65 that is supported our findings.

11.2.3. Common carp (*Cyprinus Carpio*)

Under this experiment, the growth of Common carp was recorded higher in T_1 and T_2 with significant difference (P<0.05) from T_3. Production and survival rate were satisfactory in T_1 and T_2 and recorded more or less similar results (Figure 11). Higher weight gains of Common carp in T_1 and T_2 might be due to the high availability of detritus, defecated material of grass Carp and benthic food present there compare with T_3. Therefore, feeding of Common carp directly with *Hygroryza aristata* floating grass in T_1 and indirectly in T_2 were not any significant difference in growth performance. Many authors reported the growth, production performance and economic value of Common carp that strongly supported our findings (Ibrahim, 2011; Noman *et al.,* 2011; Abbas *et al.*, 2014; Ahmed *et al.*, 2002 and Hossain *et al.*, 2014). Common carp is amongst the greatest widespread species because of its capability to be stocked in extreme densities up to 1000 kg/ha (Koehn, 2004) and to modify inland aquatic ecosystems (Weber and Brown, 2009). Parameswaran *et al.* (1971) reported that this bottom feeder fish species has a much higher growth rate than *Cirrhinus mrigala* and other Indian major Carps with similar feeding habits. Demirkalp (1992) reported that the economic value of Common carp has been increased by the growth rate in terms of length and weight, high meat yield, non-selective habitat use, tasty meat and production availability in fish farms.

11.2.4. Tilapia (*Oreochromis niloticus*)

The specific growth rate of Tilapia were 1.13±0.03 and 1.12±0.05; and the survival rate were recorded 80% and 80.86% in T_1 and T_2 respectively while the FCR was recorded 1.62 in T_3. The findings of this study are similar to the findings of many authors (Agbo*et al.*, 2011; Santiago *et al.*, 1988a; El-Saidy & Gaber, 2003; and Mbagwu and Okoye, 1990). Metwally and El-Gellal (2009) used some plant wastes for feeding of Nile Tilapia *(Oreochromis niloticus)* and recorded SGR 1.90 to 2.20 and FCR 1.59±0.09 to 1.94±0.14 and suggested adding waste material of plant origin to fish diet which promote growth rate, decrease mortality rate and increase the antioxidant activity in fish. Azad *et al*. (2004) reported the survival rate 90.63% to 91.10% of Tilapia, Carp and Pungas using low cost inputs in polyculture system. Liti *et al*. (2006) stated complete (100%) replacement of fish meal by a mixture of plant protein source in the diet of Nile Tilapia (*Oreochromis niloticus*) did not effect on growth performances rather around 36% feed production cost reduced.

However, many authors worked on replacement of fish meal by plant protein source in different times and they reported that the replacement of fish meal by plant protein source in the diet of fish feed did not affect the growth performances, feed intake and nitrogen utilization that support the present findings though we used aquatic plant as fish feed as natural condition e.g. Cheng *et al*. (2003) stated 50% fish meal replacement by a mixture of plant proteins supplemented with lysine in the diets of Rainbow trout (*Oncorhynchus mykiss*) improved growth performances, feed conversion ratio and survival rate; Kaushik *et al*. (2004) mentioned that 95% fish meal replacement by a mixture of corn gluten meal, wheat gluten, extruded wheat, soybean meal and rapeseed meal in the diets of European sea bass (*Dicentrarchus labrax*) did not affect the growth performances and nitrogen utilization; Liti *et al*. (2006) revealed that complete (100%) replacement of fish meal by a mixture of plant protein source in the diet of Nile Tilapia (*Oreochromis niloticus*) did not affect the growth performances and around 36% reduced the feed production cost; De Francesco *et al*. (2007) mentioned 75% fish meal replacement by a mixture of plant protein sources in the diets of Gilthead sea bream (*Sparus aurata*) did not affect the growth performances; Lee *et al*. (2010) shown that the complete (100%) fish meal replacement by a mixture of corn gluten, yellow soy protein concentrate and wheat gluten meal supplied with limiting EAAs and inorganic phosphate in the diets of Rainbow trout (*Oncorhynchus mykiss*) did not affect the growth performances and feed utilization; Köprücü and Sertel (2012) stated that 75% fish meal replacement by a mixture of cotton seed meal, sunflower meal and corn meal in the diets of grass Carp (*Ctenopharyngodon idella*) did not affect the growth performances and nitrogen utilization; Rossi *et al*. (2013) mentioned 50% fish meal replacement by a mixture of soy protein concentrate and barley protein concentrate in the diets of red drum (*Sciaenopsocellatus*) did not affect the growth performances, condition indices and whole-body composition; Suprayudi *et al*. (2015) publicized 50% fish meal replacement by defatted rubber seed meal in the diets of Common carp(*Cyprinus Carpio*) did not affect the growth and feeding performances; Minjarez-Osorio *et al*. (2016)confirmed that 75% fish meal replacement by a mixture of soybean protein concentrate and corn protein concentrate in the diets of in the diets of the sciaenids red drum (*Sciaenopsocellatus*) and shortfincorvina (*Cynoscionparvipinnis*) did not affect the growth performances of cultured fish.

11.3 Proximate composition analysis

Proximate composition of grass Carp, commercial floating fish feed and *Hygroryza aristata* floating grass were analyzed on the basis of moisture content (%) and dry matter content (%) as presented in Table 3 and Table 4. Dried *Hygroryza aristata* floating grass was found to contain crude protein 7.29±0.41% but 3.71±0.07 % in moisture content basis while it contained large amount of carbohydrate, 8.23±0.17 % in moisture content basis and 28.98±0.86 % in dry matter content. If *Hygroryza aristata* floating grass is dried properly and moisture content reduced approximately to 10%, then its crude protein may reach

10.26% to 11.81%. Commercial fish feed was found to contain 28.53±0.14% crude protein (Table 1) which was 3.9 times higher compared to *Hygroryza aristata* floating grass and as a result grass Carp eat more floating grass to fulfill the requirement and ultimately their stomach and gut enlarged and contain more food with other elements like lipid, carbohydrate and minerals which might supported them for proper growth, nitrogen utilization and whole body composition. The proximate compositions of grass Carp were found satisfactory level and were not significantly different (P>0.05) among the treatments (Table 4). The result of proximate composition of grass Carp of this research work was similar to the results of many authors (Afkhami *et al.*, 2011; Ćirković *et al.*, 2012; Hoseini *et al.*, 2013 and Bogard *et al.*, 2015).

Table 3. Proximate composition (mean ± SD, n=3) of *Hygroryza aristata* floating grass and commercial floating fish feed on the basis of moisture content (%) and dry matter content (%)

Proximate composition	Mean (%) ± SD		
	Hygroryza aristata (dried)	*Hygroryza aristata* (wet)	Commercial feed
Moisture	36.07±0.19 (63.93±0.19)	71.72±0.39 (28.28±0.39)	11.27±0.04 (88.73±0.04)
Crude lipid	1.42±0.08 (2.23±0.14)	0.91±0.07 (3.20±0.21)	6.64±0.22 (7.49±0.25)
Crude protein	7.29±0.41 (11.40±0.65)	3.71±0.07 (13.11±0.14)	28.53±0.14 (32.15±0.17)
Ash	17.34±0.38 (27.12±0.52)	7.71±0.14 (27.25±0.16)	8.53±0.07 (9.61±0.08)
Crude fiber	8.89±0.30 (13.91±0.45)	7.73±0.07 (27.33±0.56)	7.71±0.36 (8.69±0.41)
Carbohydrate	28.98±0.86 (45.34±1.40)	8.23±0.17 (29.11±0. 19)	37.32±0.05 (42.06±0.04)

Figures in the parenthesis indicate dry matter basis (%).

Table 4. Proximate composition of grass Carp (mean ± SD, n=3) on the basis of moisture content (%) and dry matter content (%)

Proximate composition	Treatments (mean ± SD)		
	T_1	T_2	T_3
Moisture	77.84±0.01 (22.11±0.10)	77.76±0.04 (22.21±0.03)	76.76±1.05 (23.19±1.05)
Crude lipid	1.65±0.31 (7.20±1.39)	2.15±0.38 (9.81±1.74)	2.18±0.43 (9.23±1.45)
Crude protein	18.01±0.29 (81.41±1.27)	18.31±0.42 (82.24±1.80)	18.31±0.30 (78.84±2.27)
Ash	1.40±0.16 (6.55±0.71)	1.10±0.08 (4.93±0.34)	1.48±0.10 (6.50±0.22)
Crude fiber	0.39±0.03 (1.77±0.15)	0.41±0.05 (1.86±0.21)	0.54±0.05 (2.43±0.12)
Carbohydrate	0.67±0.20 (3.05±0.92)	0.24±0.11 (1.12±0.49)	0.70±0.21 (2.98±0.76)

Figures in the parenthesis indicate dry matter basis (%).

11.4 Cost benefit analysis

A very simple cost benefit and benefit cost ratio (BCR) analysis of this research work was carried out on the basis of the total input cost such as structural cost and operational cost, return from fish production and benefit of all treatments are presented in Table 5. The total structural costs were found similar in all treatments but operational costs were found different in three different treatments depending on the feed cost. The total input cost was calculated highest BDT 1233391.00ha^{-1} in T_3 while the lowest input cost was recorded BDT318300.00ha^{-1} in T_1 that was 3.87 times lower than in T_3. The highest benefit was calculated BDT 1520597.00ha^{-1} in T_1 and the lowest benefit was observed BDT 818488.00ha^{-1} in T_3. The benefit cost ratio were found highest in T_1 (4.78) followed by T_2 (2.82) and T_3 (0.65) respectively.

Table 5. Economic analysis of production performance of cultured fish compare to utilize*Hygroryza aristata* floating grass as fish feed with commercial floating fish feed

Inputs/items/procedure	Amount (meter/weight/kg/no.)	Unit price (BDT)	Costha^{-1} (T_1)	Costha^{-1} (T_2)	Costha^{-1} (T_3)
A. Structural cost					
Bamboo splits mats (Bana)	200 m	500	100000.00	100000.00	100000.00
Knotless cott net (12ft width)	200 m	50	10000.00	10000.00	10000.00
Bamboo	70 no.	400	28000.00	28000.00	28000.00
Hapa	4 no.	2500	10000.00	10000.00	10000.00
Rope	5 kg	300	1500.00	1500.00	1500.00
Setting cost	25 days	500	12500.00	12500.00	12500.00
Total structural cost			162000.00	162000.00	162000.00
Depreciation cost per year (2 years longevity)	-	-	81000.00	81000.00	81000.00
Total structural cost per year			**81000.00**	**81000.00**	**81000.00**
B. Operational cost					
Renovation and cleaning	15 days	500	7500.00	7500.00	7500.00
Hygroryzaaristata water grass plantation	15 days	500	7500.00	7500.00	-
Labor (Floating grass and feed supply)	365 days	300	-	109500.00	109500.00
Fish seeds					
Grass Carp	7410 no.	20	148200.00	148200.00	148200.00
Black carp	1235 no.	40	49400.00	49400.00	49400.00
Common carp	1235 no.	10	12350.00	12350.00	12350.00
Tilapia	2470 no.	5	12350.00	12350.00	12350.00
Commercial floating fish feed	16261.82 kg	50	-	-	813091
Total operational cost			**237300.00**	**346800.00**	**1152391.00**
C. Gross cost (A+B)			**318300.00**	**427800.00**	**1233391.00**
D. Return					
a. Grass Carp (kgha^{-1})			6499.12	5609.57	5371.8
Return from Grass Carp		200	1299824.00	1121914.00	1074360.00
b. Black carp (kgha^{-1})			470.11	462.46	435.65
Return from Black carp		200	94022.00	92492.00	87130.00
c. Common carp (kgha^{-1})			1006.61	960.56	950.81
Return from Common carp		200	201322.00	192112.00	190162.00
d. Tilapia (kgha^{-1})			1084.86	968.64	1866.18
Return from Tilapia		150	162729.00	145296.00	279927.00
Gross revenue (a+b+c+d)			**1757897.00**	**1551814.00**	**1631579.00**
E. Net benefit ha^{-1}year^{-1}					
Net benefit (D-C)			**1520597.00**	**1205014.00**	**818488.00**
F. Economic efficiency **Benefit cost ratio (BCR)=E/C**			**4.78**	**2.82**	**0.66**

Commercial fish feed price is increasing globally which threats aquaculture as well as food security of poor all over the world. Utilization of *Hygroryza aristata* floating grass as fish feed to reduce fish production cost in aquaculture system was a new initiative in Fisheries sector of Bangladesh as well as in the world. This experiment revealed that *Hygroryza aristata* floating grass plantation as fish feed before fish stocking reduce aquaculture production cost 3.87 times which achieve economic efficiency 4.78 comparison to commercial floating feed utilization. It means that in case of 1% investment, farmers will be benefited 4.78 % for every one year adopting this technology.

12 Research highlight/findings:

- Development of technique for direct utilization of *Hygroryza aristata* floating grass as fish feed is a new initiative for aquaculture in the fisheries sector of Bangladesh;
- Aquaculture system established in the submerged open water of low-lying agriculture land through maintaining water quality by daily water exchange through tidal action;
- Fish production technology without feed cost by utilizing *Hygroryza aristata* floating grass except labor cost; and
- This technology reduces fish production cost more than 75% and thereby gains 4.7 times higher benefit compared to commercial floating feed.

B. Implementation Position

1. Procurement:

Description of equipment and capital items	PP Target		Achievement		Remark
	Phy (#)	Fin (Tk)	Phy (#)	Fin (Tk)	
(a) Office equipment i. Digital camera ii. Laptop with accessories iii. Desktop computer with accessories iv. UPS v. Laser printer vi. Scanner	i. (1) ii. (1) iii. (1) iv. (1) v. (1) vi. (1)	i. 25000 ii. 60000 iii.60000 iv.10000 v. 20000 vi. 10000	i. 100% ii. 100% iii. 100% iv. 100% v. 100% vi. 100%	i. 100% ii. 100% iii. 100% iv. 100% v. 100% vi. 100%	100% achievement
(b) Lab & field equipment Apparatus i. Spectrophotometer (1) ii. Refractometer (1) Chemicals i. Varionitra-X reagent ii. vario total phosphate reagent iii. Vario AM Tube test reagent iv. Methyl orange indicator v. Hydrochloric acid (HCl) vi. Sodium salphate (Na_2SO_4) vii. Potasiumsalphate (K_2SO_4) viii. Copersalphate ($CuSO_4$)	i. (1) ii. (1) i.1 pac. 100p ii. 1 pac. 100p iii. 1 pac. 100p iv. 100g v.2.5 L vi. 2.5 Kg vii. 2.5 Kg viii. 2.5 Kg ix. 2.5 Kg	i. 465000 ii.33000 i.55000 ii. 45000 iii. 25000. iv. 3000 v. 4500 vi. 4500 vii. 10000 viii. 6500 ix. 4365	Apparatus i. 100% ii. 100% Chemicals i.100% ii. 100% iii. 100% iv. 100% v. 100% vi. 100% vii. 100% viii. 100% ix. 100%	Apparatus i. 100% ii. 100% Chemicals i.100% ii. 100% iii. 100% iv. 100% v. 100% vi. 100% vii. 100%	

Description of equipment and capital items	PP Target		Achievement		Remark
	Phy (#)	Fin (Tk)	Phy (#)	Fin (Tk)	
ix. Sodium thiosalphate ($Na_2S_2O_3$) x. Sodium carbonate (Na_2CO_3) xi. Sodium hydroxide (NaOH) xii. Boric acid (H_3BO_3) xiii. Methyl red xiv. Methyl blue xv. Selenium powder, xvi. Sulfuric acid (H_2SO_4) xvii. Formalin	x. 2.5 Kg xi. 2.5 Kg xii. 2.5 L xiii. 250 g xiv. 250 g xv. 175 g xvi. 2.5 L xvii. 2.5 L	x.5000 xi.4500 xii.6500 xiii. 7500 xiv. 6250 xv. 17500 xvi. 4500 xvii.10500	x. 100% xi. 100% xii. 100% xiii. 100% xiv. 100% xv. 100% xvi. 100% xvii. 100%	viii. 100% ix. 100% x. 100% xi. 100% xii. 100% xiii. 100% xiv. 100% xv. 100% xvi. 100% xvii. 100%	
(c) Other capital items (Furniture) i. Computer table (1) ii. Computer chair (1) iii. File cabinet (1) iv. Steel Almirah (1)	i. (1) ii. (1) iii. (1) iv. (1)	i. 5000 ii. 3500 iii. 20000 iv. 20000	i. 100% ii. 100% iii.100% iv. 100%	i.100% ii. 100% iii.100% iv.100%	

2. **Establishment/renovation facilities:** Not applicable

Description of facilities	Newly established		Upgraded/refurbished		Remarks
	PP Target	Achievement	PP Target	Achievement	

3. **Training/study tour/seminar/workshop/conference organized:**

Description	Number of participant			Duration (Days/weeks/ months)	Remarks
	Male	Female	Total		
(a) Training	-	-	-	-	
(b) Seminar	28	2	30	1 day	Seminar on "Development of sustainable aquaculture system in the inundated low-laying agriculture land in the coastal region of Bangladesh"

C. Financial and physical progress

Fig in Tk

Items of expenditure/activities	Total approved budget	Fund received	Actual expenditure	Balance/ unspent	Physical progress (%)	Reasons for deviation
A. Contractual staff salary	315775	302477	302477	0	96	Not applicable
B. Field research/lab expenses and supplies	1877960	1877960	1877960	0	100	
C. Operating expenses	137225	137225	137255	0	100	
D. Vehicle hire and fuel, oil & maintenance	100000	100000	100000	0	100	

E. Training/workshop/seminar etc.	70000	70000	70000	0	100	
F. Publications and printing	75000	15000	15000	0	100	
G. Miscellaneous	50000	48050	48050	0	96	
H. Capital expenses	233000	233000	233000	0	100	

D. Achievement of Sub-project by objectives: (Tangible form)

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output(i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)
i.Utilization of *Hygroryza aristata* floating grass as fish feed	i. Site selection for project work ii. Experiment setting iii. Bamboo split made mat and net setting iv. *H. aristata* floating grass plantation v. Fish fingerling purchase and stocking vi. Supply of *H. aristata* floating grass to fish as fish feed	i. Aquaculture facilities improved ii. Use of *H. aristata* as fish feed increased	i. Development of sustainable aquaculture system in the inundated low-lying agriculture land ii. Local consumption increase
ii. Utilization of the submerged low-lying agriculture land and tidal water for aquaculture system with maintaining good water quality	i. Experiment setting in submerged low-lying agriculture land ii. Purchase and setting bamboo split made mats and net in open side to exchange tidal water daily iii. Land preparation for fish stocking iv. Fish fingerling purchase and stocking v. Supply of *H. aristata* to fish as feed vi. Supply of industrial floating fish feed vii. Rearing of stocked fish in the experiments viii. Water quality data collection ix. Fish sampling and growth measurement x. Arrange seminar/workshop	i. Structural development of this suggested fish culture area with better water quality	i. Employment and income of farmer increase ii. Fish supply between demand and supply will available
iii. Determination of proximate composition of . *aristata* and stocked	i. Experiment setting ii. *H. aristata* floating grass plantation	i. Result of proximate composition	i. Acquire knowledge of proximate

Specific objectives of the sub-project	Major technical activities performed in respect of the set objectives	Output(i.e. product obtained, visible, measurable)	Outcome(short term effect of the research)
fish in relation to growth performance	iii. Fish fingerling purchase and stocking iv. Supply of *H. aristata* to fish as fish feed v. Supply of industrial floating feed to comparison the effectiveness of *H. aristata* as feed for fish vi. Collection of *H. aristata* floating grass sample and fish sample for proximate composition analysis vii. Sending of sample to the Lab. for analysis viii. Analysis of proximate composition	of *H. aristata* and fish	composition of *H. aristata* and fish and nutritive value.
iv. Examine biological, economical and environmental advantages achieved through new interventions proposed aquaculture systems.	i. Economic analysis ii. Cost-benefit analysis iii. Benefit Cost Ratio (BCR) analysis	i. Information an ideal condition of this culture system	i. An ideal package for aquaculture in low-lying coastal land with low cost feed available

E. Materials Development/Publication made under the Sub-project:

Publication	Number of publication		Remarks (e.g. paper title, name of journal, conference name, etc.)
	Under preparation	Completed and published	
Technology bulletin/ booklet/leaflet/flyer etc.			
Journal publication	1	-	Climate resilience aquaculture in the coastal region: Economics improvement and livelihood enhancement of coastal people of Bangladesh (submitted)
Information development			
Other publications, if any (abstract submission for 6th ICFA, conference, Thailand)	1	-	Utilization of *H. aristata* floating grass in aquaculture system: an alternative fish feed for coastal aquaculture in Bangladesh

F. Technology/Knowledge generation/Policy Support (as applied):

i. Generation of technology (Commodity & Non-commodity)

Technology developed on increased aquaculture production from the inundated low-lying land at the coastal region by applying *H. aristata* as low cost feed.

Sustainable coastal aquaculture system was established while a new plant protein source was used as fish feed in aquaculture system which will be reduced fish production cost in aquaculture system in Bangladesh.

iii. Technology transferred that help increased agricultural productivity and farmers' income

This technology dissemination through local community participation and farmers to farmer's dispersion increased agricultural productivity and farmers' income.

iv. Policy Support

Not applicable

G. Information regarding Desk and Field Monitoring

i) Desk Monitoring[description & output of consultation meeting, monitoring workshops/seminars etc.):

a. CRG Sub- Project Implementation Progress Workshop/Seminar held in BARC, Farmgate Dhaka on 21 December 2017. Found satisfactory
b. CRG Sub-Project Final output Workshop held in BARC, Farmgate Dhaka on 19-20 September 2018. Found satisfactory

ii) Field Monitoring (time& No. of visit, Team visit and output):

a. Monitoring team of PIU-BARC, NATP-2 visited the project field on 17.02.2018. I showed the activities of project through power point presentation.
b. They observed the lab and field equipment and provide some advices which have been followed accordingly.

H. Lesson Learned/Challenges (if any)

- Utilization of *Hygroryza aristata* floating grass as potential fish feed for aquaculture;
- Utilization of *Hygroryza aristata* as feed ingredient in industrial pellet/floating feed as this better in quality and contribution in growth performance of fish; and
- Increased scope for utilizing of industrialized inundated low-lying agriculture land for aquaculture in the coastal region for increasing fish production, nutrition security and socio-economic development.

I. Challenges (if any)

Motivation and change in social attitude for utilization of enormous unused inundated low-lying lands for aquaculture in the coastal region is a great challenge.

04.03.19

Signature of the Principal Investigator

Date ....Md. Moazzem Hossain

Seal

Principal Investigator
Development of aquaculture system
in the coastal region of Bangladesh
Dept. of Fisheries Management, PSTU

4/3/19

Counter signature of the Head of the organization/authorized representative

Date ....

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