Sub-Project ID: 037

Program Based Research Grant (PBRG)

Sub-project Completion Report

on

Improvement of Existing Fattening Technology of Carp and High Valued Small Indigenous Species (SIS) through Good Aquaculture Practices (GAP) in Different Agro-ecosystems

Sub-project Duration
27 December 2017 to 20 December 2021

Coordinating Organization
Fisheries Division
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

Project Implementation Unit
National Agricultural Technology Program Phase II Project
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

November 2021

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Implementing Organizations

Department of Fisheries
University of Rajshahi
Rajshahi-6205

Department of Aquaculture
Patuakhali Science & Technology University
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Project Implementation Unit
National Agricultural Technology Program Phase II Project
Bangladesh Agricultural Research Council
Farmgate, Dhaka-1215

November 2021

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Project Implementation Unit
National Agricultural Technology Program-Phase II Project (NATP-2)
Bangladesh Agricultural Research Council (BARC)
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Abbreviation and Acronyms

%	:	Percentage	M	:	Meter
ºC	:	Degree Centigrade	mg/l	:	Milligram Per Liter
AOAC	:	Association of Official Analytical Chemists	MPN	:	Most Probable Number
BARC	:	Bangladesh Agricultural Research Council	MOC	:	Mustard Oil Cake
BCR	:	Benefit Cost Ratio	NATP-2	:	National Agricultural Technology Program-Phase II
BDT	:	Bangladesh Taka	ND	:	Below Detection limit
Cd	:	Cadmium	Pb	:	Lead
cfu/g	:	Colony Forming Units Per Gram	PBRG	:	Program Based Research Grant
CO_2	:	Carbon Dioxide	PCR	:	Project Completion Report
DMRT	:	Duncan's Multiple Range Test	PIU	:	Project Implementation Unit
DO	:	Dissolved Oxygen	PSTU	:	Patuakhali Science and Technology University
DoF	:	Department of Fisheries	RU	:	Rajshahi University
FAPAD	:	Foreign Aided Projects Audit Directorate	SD	:	Standard Deviation
FGD	:	Focus Group Discussion	SE	:	Standard Error
FDA	:	Food and Drug Administration	SGR	:	Specific Growth Rate
FoF	:	Faculty of Fisheries	SIS	:	Small Indigenous Species
G	:	Gram	SPC	:	Standard Plate Count
GAP	:	Good Aquaculture Practices	SPSS	:	Statistical Package for Social Science
GDP	:	Gross Domestic Product	TDS	:	Total Dissolved Solid
GoB	:	Government of Bangladesh	TSP	:	Triple Super Phosphate
Ha	:	Hectare	USA	:	United States of America
IFAD	:	International Fund for Agricultural Development	WB	:	World Bank
Kg	:	Kilogram	yr	:	Year

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Executive Summary

Safe fish production through carp fattening by the aquaculture entrepreneurs in commercial ponds and SIS fish farming by the distressed women in homestead ponds is potential for drought prone and coastal areas of Bangladesh. Lack of guidelines in selecting appropriate stocking size, density and combination of species with high feed cost are hindering fish production. Moreover, increased mortality in live fish transportation and off flavor in fishes are adversely affecting the sustainability of carp fattening. In order to address these problems, series of experiments were conducted during 2018 to 2020 in Rajshahi and Patuakhali districts, Bangladesh. In year-1, suitable species combination for carp fattening was determined under three treatments (T_1: surface-30%, column-40% and bottom feeder-30%; T_2: surface-40%, column-30% and bottom feeder-30%; and T_3: surface-35%, column-35% and bottom feeder-30%) and suitable species of SIS fish for SIS-carp farming was determined under three treatments (T_1: Shing, *H. fossilis*; T_2: Magur, *C. batrachus*; and T_3: Gulsha, *M. cavasius*). In year-2, stocking density (fishes/ha) of carp was optimized for fattening under three treatments (T_1: 2470; T_2: 3705; and T_3: 4940) and that of SIS fish (*C. batrachus*) for SIS-carp farming under three treatments (T_1: 37,050; T_2: 74,100; and T_3: 111,150). In year-3, feed suitability was determined under three treatments (T_1: regular feeding of 100% factory feed; T_2: regular feeding of 70% factory feed; and T_3: restricted feeding once per week of 70% factory feed) for carp fattening and SIS-fish farming through two separate experiments. Two more experiments like live fish transportation (March-June, 2020) under three treatments of loading densities (kg fish/ton water) in truck (T_1: 80; T_2: 100; and T_3: 120) and organoleptic study (October, 2020) under three treatments of carp fattening management (T_1: inorganic fertilizers, feed and inclusion of silver carp under GAP management; T_2: organic and inorganic fertilizers, feed and inclusion of silver carp; and T_3: organic and inorganic fertilizers, feed and exclusion of silver carp) were also conducted. Treatments were replicated thrice under the experiments. Overwintered carp species (Catla, *Gibelion catla*; Silver carp, *Hypophthalmichthys molitrix*; Rui, *Labeo rohita*; Mrigal, *Cirrhinus cirrhosus* and Common carp, *Cyprinus carpio*) were used for carp fattening. Carps (*H. molitrix*-500/ha, *G. catla*-250/ha and *L. rohita*-250/ha) were used as co-species of SIS fish farming. Fish growing period (July-December) and protein content in diet (25% for carp fattening and 35% for SIS fish farming) were same for all the experiments. Water quality and GAP aspects (concentration of Pb, Cd and pathogenic bacteria) were monitored and found mostly within acceptable range. Farming practices and problems were also identified through conducting a base line survey and several FGDs in first year. Experimental findings indicated that surface feeder dominant (40%) combination with lowest density (2470 fishes/ha) was profitable for carp fattening whereas Magur, *C. batrachus* with medium density (74100 fishes/ha) was found profitable for SIS-carp farming. Use of factory feed (70%) under restricted feeding regime was found profitable both for carp fattening and SIS-carp farming. Lower fish loading density (80 kg/ton water) increased the fish survival. Fish produced under good aquaculture practices (GAP) was found with natural taste. Effort was taken to increase the capacity of the farmers through manual based group discussion and training. Findings were also disseminated through producing leaflet and scientific paper and conducting field day and workshop.

Efforts through visiting research sites frequently and conducting meeting and workshops regularly were taken by the coordination part to monitor the progress of project activities at different stages and thereby to provide guidelines to the implementing organizations to adjust the lacks and gaps as well. With addressing the farming problems, separate technologies on GAP based carp fattening and SIS-carp farming were developed for both drought prone and coastal areas. Moreover, techniques to remove the off flavour in harvested carps and to maintain the appropriate loading density for live fish transportation in truck were also recommended for sustainability of the carp fattening. Technologies developed on carp fattening and SIS-carp farming and new information generated on removal of off flavour and transportation of live fishes were disseminated through conducting and participating workshop and conference at home and abroad; developing printed materials like leaflets; producing scientific articles in reputed journals and popular articles in print medias; and exploring documentary video clips through TV channels. As an immediate impact, participating farmers were capable well to increase fish production, consumption and income in the study areas. Harvested fishes (carps) were also found safe with natural taste (without off flavor) for consumption. Apart from the fish farming under good aquaculture practices and live fish transportation under lower loading density, some other important lessons learned in this project included local supply of the overwintered carps for timely stocking in fattening ponds, partial harvesting of the carps for getting fair price and taking pre-caution to protect the fishes during natural calamity. Judicial use of feed and fertilization, smooth supply of over wintered carps and effective mitigation of some risks like price fall of harvested fish, unavailability of inputs and labour especially during corona pandemic were noted as major challenges for this project. Some suggestions on multi location testing of the generated technologies, organizing training and workshop based on project findings and conducting demonstration /research for production of over wintered carps and restricted feeding regime for fishes were also forwarded for future planning.

Key words: Carp fattening, SIS, Homestead pond, Poluculture, Drought prone.

PBRG Sub-project Completion Report (PCR)

A. Sub-project Description

1. **Title of the PBRG sub-project : Improvement of Existing Fattening Technology of Carp and High Valued Small Indigenous Species (SIS) Through Good Aquaculture Practices (GAP) in Different Agro-Ecosystems**

2. **Implementing organization :** Department of Fisheries, University of Rajshahi, Rajshahi and Department of Aquaculture, Faculty of Fisheries, Patuakhali Science and Technology University, Patuakhali

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

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4. Sub-project budget (Tk)

Total approved budget	:	Tk. 3,46,05,754.00
A. BARC component	:	Tk. 13,00,000.00
B. RU component	:	Tk. 2,07,06,230.00
C. PSTU component	:	Tk. 1,25,99,524.00

5. Duration of the sub-project

5.1 Start date (based on LoA signed): 27 December 2017
5.2 End date: 20 December 2021

6. Background of the sub-project

Fisheries sub-sector of Bangladesh is highly diverse in resource types and species and thus, it has emerged as one of the leading nations in freshwater aquaculture production during recent years and its growth rate is quite comparable to that of China and India. It is extremely important to the national economy, accounting for 3.50% of GDP and 25.72% of agricultural GDP. About 60% of animal protein intake comes from fisheries sub-sector and more than 11% people directly or indirectly depend on it for their livelihood. As in many other countries, aquaculture production in Bangladesh has rapidly increased in recent years because of adoption of various improved aquaculture technologies. During 2000-2001 to 2018-2019, Bangladesh's annual total fish production rate is increased continuously, with a peak of 7.32% in 2009-2010. Aquaculture contributes 56.76% to the total fish production (DoF, 2020). It has further potentials for the development and promotion of appropriate technologies through effective utilization of the water bodies under different agro-ecological zones with the involvement of both entrepreneurs and distressed people specially the women.

Carp polyculture in pond is the most popular technique among the majority of fish farmers and it contributes 52.06% of the total pond production in Bangladesh (DoF, 2019). Despite the popularity of current polyculture technique, carp fattening technique has added a new dimension in commercial fish farming to produce and market larger sized carps using larger stocking size of fishes in ponds compared to that of smaller stocking size practiced traditionally. The fish fattening technique has tremendous potentials for producing and marketing larger size fishes within shorter production period involving different enterprises engaged in farming, marketing and overall value chain. Despite of high demand of large fish in the market, fish farmers are forced to produce small to medium size of fish due to lack of proper and farmer-friendly fish fattening technologies, live fish transportation and marketing technologies, market infrastructure and value chain. Institutional credit facilities, support from government extension services and research institutions is also limiting the potential fish farming and marketing systems. Within this situation, some advanced fish farmers and entrepreneurs have started fish fattening and marketing live fish following traditional to semi-improved production and marketing approaches. Capturing the lessons learnt and best practices from those advanced fish farmers and entrepreneurs, conducting systematic research and extension services for scaling up can bring enormous changes in fish fattening practices at entrepreneur level. Besides, promoting the farming of SIS fishes can ensure the effective utilization of the homestead ponds especially by the poor women in climatically vulnerable drought and coastal areas of Bangladesh. Changes in all these aspects will ultimately increase overall fish production and supply of live fish (larger sized carps) in the market.

Since the concept of carp polyculture is found to utilize the maximum species of three different niches in pond ecosystem, drought events in northern and salinity in southwestern Bangladesh are considered to be major problems for pond polyculture to maximize production through utilization of the niche-based species. Moreover, increased mortality in live fish transportation and off flavor in fishes are adversely affecting the sustainability of carp fattening. Such problems can be minimized through developing good aquaculture practice (GAP) based carp fattening technology for the entrepreneurs and promoting aquaculture of SIS fishes in homestead ponds for the poor women. In spite of exploring the potentials of the ponds for aquaculture development under northern drought prone area (Hossain *et al*., 2009; Hossain, 2011) and southern coastal region (Islam *et al*., 2008) and documenting the importance of GAP towards safe fish production, comprehensive research efforts are not yet found to address the aquaculture problems of drought prone and coastal regions of Bangladesh. Thus, the present study aims at improvement of existing fattening technology of carp and high valued SIS fish farming through good aquaculture practices (GAP) in different agro-ecosystems.

7. Sub-project general objectives

- To capture good aquaculture practices and develop sustainable technology for drought prone and coastal areas of Bangladesh.
- To adapt high valued SIS fish farming as a means of short term income generation for distressed rural women by utilizing homestead water bodies.
- To increase the capacity of fish farming entrepreneurs and farmers and disseminate and popularize the technologies.

8. Sub-project specific objectives

BARC coordination component

i) to ensure smooth and efficient implementation of sub-project activities to achieve desired sub-project outputs within the stipulated timeframe under strengthened capable research management system;
ii) to coordinate project implementation efforts and integration of activities to generate desired information /technology as per methodology of the sub-projects;
iii) Identify operational deviations and addressing constraints/problems (if any) under a process of strong and regular monitoring of the sub-project activities;
iv) to upgrading the level of output of the sub-project through reviewing of yearly technical progress;

v) Collect and collate sub-project data, finding and observation and production of compiled Project Completion Report (PCR);

RU component

i) to identify existing carp fattening and good aquaculture practices and thereby develop sustainable technology for carp fattening by the entrepreneurs in ponds.
ii) to promote farming of high valued SIS fish by the distressed women in homestead ponds;
iii) to develop viable technology for live fish transportation and strategy for marketing and market linkages.
iv) to increase capacity of farmers, entrepreneurs and market players; and
v) to disseminate findings and recommendation through sharing technical reports and scientific publications in popular journals.

PSTU component

i) to develop sustainable technology for carp fattening by the entrepreneurs in pond;
ii) to promote farming of high valued SIS fish by the distressed women in homestead pond;
iii) to increase capacity of farmers, entrepreneurs and market players and
iv) to disseminate findings and recommendation through sharing technical reports and scientific publications in popular journals.

9. Implementing locations

Fisheries division of BARC carried out all of the coordination activities. The sub-project research activities were implemented in Paba and Tanore upazilas under Rajshahi (drought prone area) and Kalaparaupazila under Patuakhali district (salt water intrusion affected coastal area) of Bangladesh.

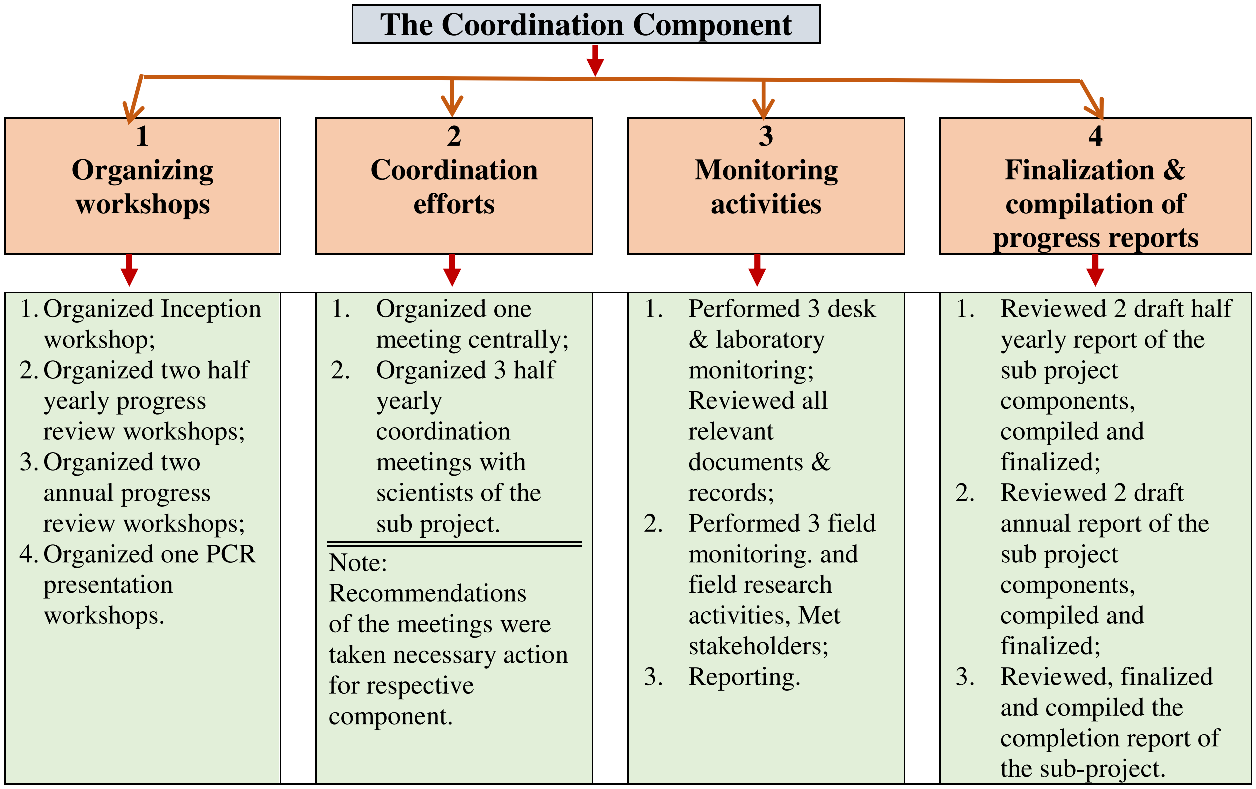
10. Methodology in brief

10.1. Activity implementation approach for the Coordination component

The Coordination component as the responsible unit of the sub-project to initiate all potential efforts in the process of implementation of each component under the sub project so that the general objectives and goal of the sub project can be achieved through smooth and successful completion of each of the specific objectives as per activity time plan of the sib-project document. To ensure that, the Coordination component, taken into consideration its own activity and objectives and duration of the sub project, thus accordingly designed its own plan of activity (approach) for the proposed period. Following are the major activities carried out by the Coordination component under the plan:

a. Organizing seminars/workshops.
b. Monitoring the sub-project activities (specifically financial and research activities);
c. Coordination activities within the component projects.
d. Review and compilation of half yearly and annual research progress reports.

The implementation approach and activities there under for the Coordination component of the sub project shown in the following diagram:



Recommendations of the inception workshop, half yearly and annual research progress review workshops and different coordination meetings are furnished hereunder in **Appendices- BARC: A - D.**

Following table presenting the summary statement of achievements performed by the Coordination component of the sub project:

Summary statement of achievements		
Name of activities	**Performance against each activity**	**Remark**
Inception workshop	Organized centrally at BARC in November' 2018	Attended all PI, Co PI & expert members.
Revision of PP	Done as per recommendations of Inception Workshop	
H-Y-prog. Review Workshop (Date)	Organized centrally at BARC in March' 2019, January'2020.	Attended all PI, Co PI & expert members
Ann. Prog. review Workshop (Date)	Organized centrally at BARC in July' 2019 & in September' 2020	Attended all PI, Co PI & expert members..
Coordination meeting (No)	03 *07.02.19, 19.10.19 & 25.06.20*	One Coordination meeting held centrally.
Monitoring of field and Lab activities	04 *(RU& PSTU)*	Covered all components under sub-project.
Financial achievement	Approx. 100% of released money & 98.3% of total approved budget	Delay in Proc. Plan approval and Covid-19 incidence hampered desired progress
Reporting performance	Provided sub-project inception reports, SoE, Half yearly and Annual compiled progress reports of all sub- project components as per planned time frame.	Major reports are: • Inception report (1 no); • Compiled half yearly progress report (3 no); • Compiled annual progress report (2 no); • Monitoring reports (3 no).

Pictorial views of
Different workshops, coordination meetings and field monitoring activities

10.2. Research methodology (Combined)

10.2.1. Methodology followed in first year (2018) by ccomponent 1 (RU)

1. **Baseline survey :** A baseline survey and two experiments (determination of suitable species combination for carp fattening and determination of suitable species of SIS fish for SIS-carp farming) were conducted in 2018.

1.a. Selection of fish farmer/ponds

A total of 36 ponds/ farmers were selected as core farmers (contact farmers) from two upazilas like Paba and Tanore upazila of Rajshahi district, Bangladesh (9 ponds/farmers for each experiment in each upazila) for conducting the experiments on carp fattening and SIS fish farming (Fig1**.**). In case of carp fattening, mean area (ha) and depth (m) of the ponds varied from 1.05±0.16 to 1.14±0.17 and 1.68±0.03 to 1.72±0.01, respectively in Paba and 0.49±0.43 to 0.53±0.15 and 1.66±0.02 to 1.69±0.02, respectively in Tanore. In case of SIS-carp farming, mean area and depth of the pond was 0.05±0.00 ha and 1.37±0.02 to 1.40±0.01m, respectively in Paba and that of 0.04±0.00 ha and 1.35±0.02 to 1.39±0.01m, respectively in Tanore.

1.b. Questionnaire based survey and FGD

At the start of the sub-project a base line survey was conducted to know the socio-economic condition of the farmers. Purposively a questionnaire was developed, tested and finalized for data collection. The ratio of core and non-core farmers was maintained as 1:1 during survey. Several FGDs were also conducted to capture the existing fattening/farming practices, identify the farming problems and to facilitate the technical piloting of the project.

2. Exp 1: Determination of suitable combination for carp fattening and SIS election

2.a. Experimental design

Two separate experiments (each with 3 treatments and 3 replications) on carp fattening and SIS-carp polyculture in ponds were conducted. Suitable species combination for carp fattening was determined under three treatments (T_1: surface-30%, column-40% and bottom feeder-30%; T_2: surface-40%, column-30% and bottom feeder-30%; and T_3: surface-35%, column-35% and bottom feeder-30%). Stocking density (2470 fishes/ha) was same for all the treatments. Suitable species of SIS fish for SIS-carp farming was also determined under three treatments (T_1: Shing, *H. fossilis*; T_2: Magur, *C. batrachus*; and T_3: Gulsha, *M. cavasius*). Stocking densities of SIS fishes (37,050 fishes/ha) and co-species (Silver carp, *H. molitrix*-494/ha; catla, *G. catla*-247/ha; and rui, *L. rohita*-247/ha) were same for all the treatments. Fish growing period (July to December, 2018) was same for both experiments.

2.b. Pond management

Aquatic weeds form all the experimental ponds were removed manually (Plate 1). Unwanted fishes and other species were also removed through repeated netting. Both wild (Indian major carps) and hatchery (SIS fishes and exotic carps) seeds were used for stocking into the ponds under different treatments. Carp seeds were used following overwintering process whereas seeds of SIS fishes were shifted from nursery rearing to farmer managed grow out ponds for stocking (Plate 2). Considering the soil and water quality of *barind* area of Bangladesh, low alkalinity and high turbidity mitigation strategy for the ponds was followed through lime treatment (500 kg/ha in Tanore and 250 kg/ha in Paba as basal dose; 60kg/ ha/fortnight in Tanore and 50kg/ ha/fortnight in Paba as periodic dose) was done (Plate1). Ash treatment (5000 kg/ha as basal and 1250 kg/ha/fortnight as periodic dose) was also done for turbid ponds under *barind* area. Both lime and ash treatment in ponds under drought prone area was done after Hossain (2011). Guideline for GAP (Good Aquaculture Practice) aspects was followed after DoF (2012) and no organic manure was used except limited use of inorganic fertilizers(urea: basal dose of 40 kg ha^{-1} and periodic dose of 1.0 $kgha^{-1}$ day^{-1}; triple super phosphate, TSP: basal dose of 40 kg ha^{-1} and periodic dose of 1.0 $kgha^{-1}day^{-1}$) to enhance the natural feed. Basal fertilization was done after three days of liming. Fishes were fed (twice daily) with supplementary feed (25% protein content for carp fattening and 35% protein content in SIS fish farming) (Plate2). Frequent field visits were also made for monitoring the pond management under different experiments (Plate4).

2.c. Monitoring of water quality and fish growth

Water quality parameters of the experimental ponds were monitored between 09:00 AM to 10:00 AM in each month (Plate 3). Water temperature (°C) was recorded with the help of a Celsius thermometer at 20-30 cm depth of water. Water transparency (cm) was measured by a Secchi disk. Dissolved oxygen (mg/l), pH, alkalinity (mg/l) and ammonia-nitrogen (mg/l) were determined by the help of a HACH kit (FF2, USA). Total dissolved solids (TDS) was determined by a Multimeter (HQ 40 D, HACH, USA). Plankton concentration in water was determined by the help of a microscope after Stirling (1985). Fortnightly sampling was done for monitoring fish growth and adjusting the feeding ration (Plate 3). Initial stocking weight, final weight, weight gain, SGR, survival rate and yield were calculated after Brett and Groves (1979) as follows:

Initial weight (g) = Weight of fish at stock
Final weight (g) = Weight of fish at harvest
Weight gain (g) = Mean final weight (g) - Mean initial weight (g)

$$\text{SGR } (\%, \text{bwd}^{-1}) = \frac{L_n \text{ final weight} - L_n \text{ initial weight}}{\text{Culture period}} \times 100$$

$$\text{Survival rate } (\%) = \frac{\text{No. of fish harvested}}{\text{No. of fish stocked}} \times 100$$

Fish yield (kg/ha) = Fish biomass at harvest – Fish biomass at stock

2.d. Monitoring of GAP aspects

Before conducting the experiments (especially for carp fattening), pond water and fish feed samples were collected and heavy metals like lead and cadmium contents were determined through AAS (Atomic Absorption Spectrophotometer) technique. Pathogenic microbial load was also enumerated monthly in soil and water as a part of monitoring the GAP aspects. MPN (Most Probable Number) method was followed for enumerating the pathogenic microbial load after FDA (2002).

2.e. Exploring the economics of fish farming

Total cost (including fixed and variable costs), total return, net benefit and cost benefit ratio (BCR) were calculated after Shang (1990) to explore the economics of fish farming under different treatments of the experiments on both carp fattening and SIS-carp farming in ponds.

2.f. Data analyses

*S*urvey data was subjected to descriptive analysis. Experimental data on water quality, fish growth and yield, economics of fish farming and GAP aspects were subjected to one way ANOVA (Analysis of Variance) using computer software SPSS (Statistical Package for Social Science). The mean values obtained under different treatments of the experiments were also compared to see the significant difference from the DMRT (Duncan Multiple Range Test) after Gomez and Gomez (1984). When a main effect was significant, the ANOVA was followed by Duncan Multiple Range Test (DMRT) at 5% level of significance. The percentages data were analyzed using arcsine-transformed data. All data were expressed as mean ± standard error (SE).

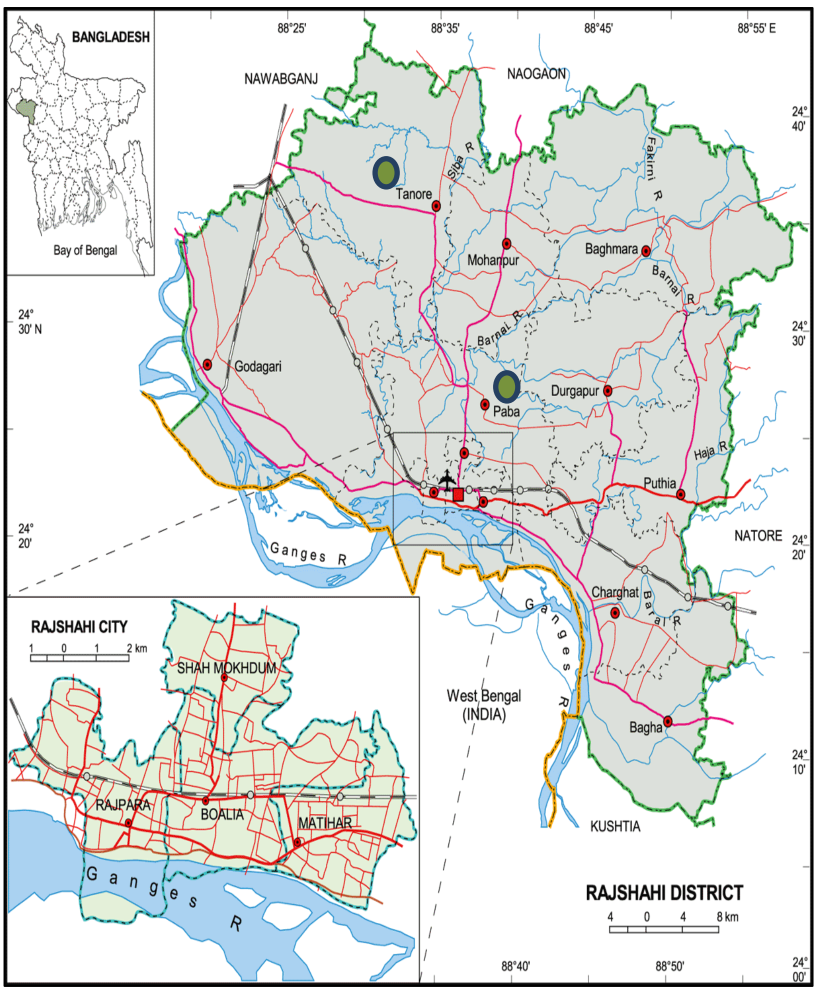


Fig. 1. Study area in Paba and Tanore upazila (sub-district) of Rajshahi district, Bangladesh.

(a) (b)

(c) (d)

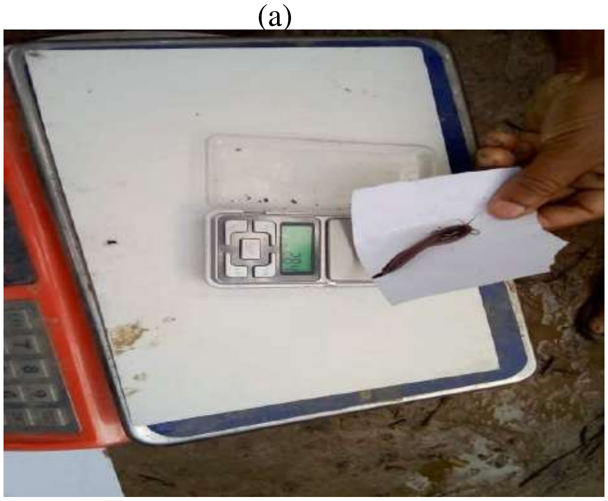
Plate 1. Pre-stocking management (a: weed removal; b-d: lime and ash treatment in ponds).

(a) (b)

(c) (d)

Plate 2. Stocking and post stocking management (a: SIS fish seed distribution; b to c: stocking; d: fish feed application into the ponds).

(a) (b)



(c) (d)

Plate 3. Pond monitoring (a to b: water quality monitoring; c to d: fish growth study) in ponds.

(a)

(b)

(c)

(d)

Plate 4. Research site visit (a: visit by Coordinator, PBRG-037; b: visit by Director, NATP2, BARC; c: visit by Chairman, Department of Fisheries, RU; d: visit by monitoring team, BARC).

(a)

(b)

(c)

(d)

Plate 5. Live fish transportation study (a: loading of live fish for transportation from Rajshahi to Dhaka; b: water quality monitoring at start; c: water quality monitoring at end; d: recording fish mortality at end).

(c)

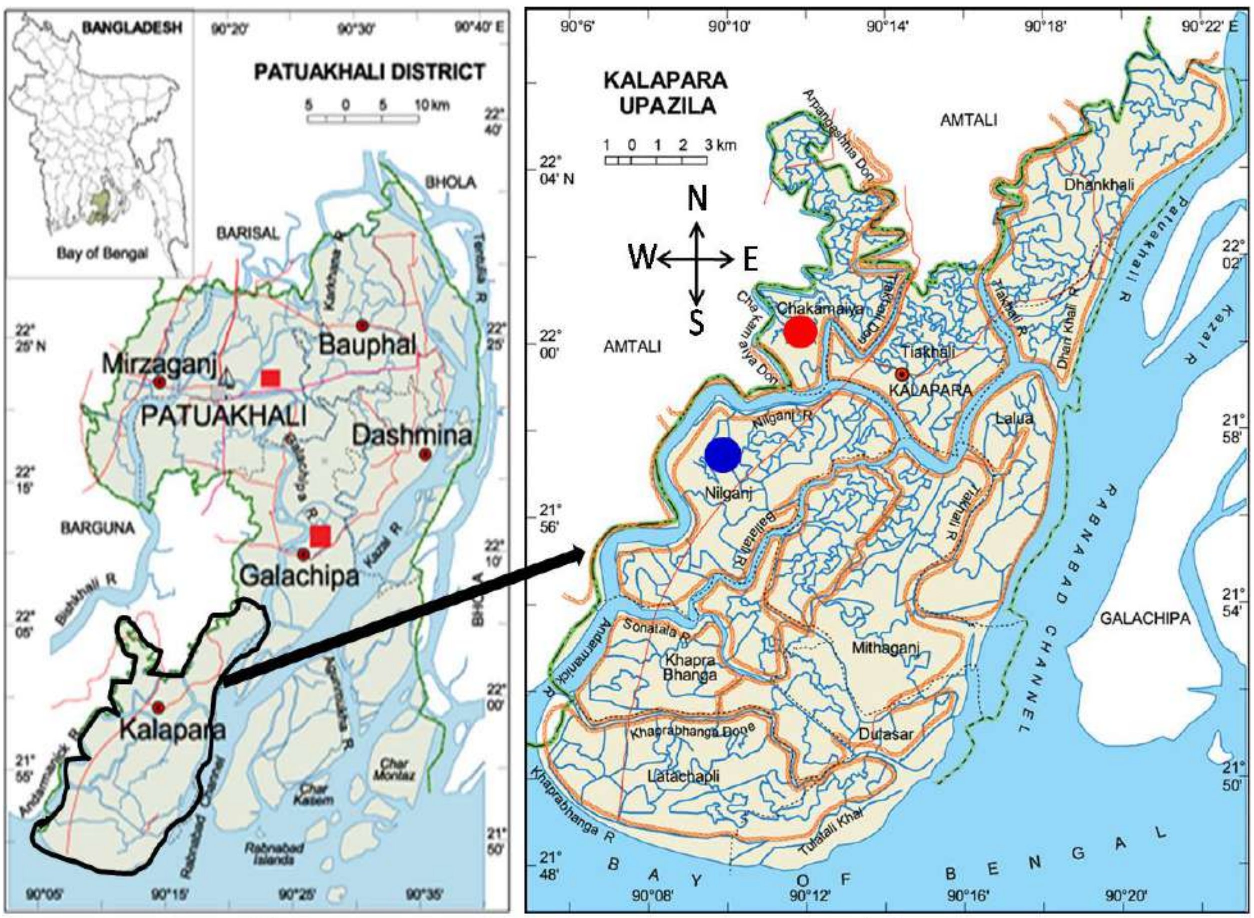
(d)

Plate 6. Capacity building of the farmer, organoleptic study and findings sharing workshop (a: farmer group discussion; b: briefing on organoleptic study; c: Field day; d: Unveiling of the leaflets).

10.2.2. Methodology followed in first year (2018) by ccomponent 2 (PSTU)

1. Baseline survey

At the start of the sub-project a baseline survey was conducted to select the commercial and homestead ponds and to know the socio-economic condition of the fish farmers. A questionnaire was purposively developed, tested and finalized with consultation to the experts from University of Rajshahi and Bangladesh Agricultural Research Council (BARC).



A) B)

Fig. 2 Map showing the location of the study area at Kalapara Upazila of Patuakhali district; A) Patuakhali district, B) Kalapara Upazila; Red and blue circles indicates Chakamaiya and Nilganj Union at Kalapara Upazila. 🔴 Chakamaiya 🔵 Nilganj.

2. Exp. 1. Determination of suitable species combination for carp fattening in ponds under coastal area

The experiment was conducted in farmer’s ponds at Anipara and Kathalpara village under Chakamaiya union in Kalaparaupazilla of Patuakhali District (Fig. 2) during the period from July 2018 to March 2019, in order to determine the suitable species combination for carp fattening in ponds under south-west coastal areas of Bangladesh.

2.a. Description of the ponds

The area of each pond was about 25 decimal with an average depth of almost 1.2 m. As most of the farmer's ponds in experimental area were irregular shaped so the ponds were renovated as standard aquaculture pond. The ponds were completely independent and well exposed to sunlight. The ponds had inlet and outlet and facilities to provide water as and when needed from the canal water using a flexible plastic pipe. Water quality was maintained properly through routine exchange of water.

2.b. Pond preparation

The following steps were followed for pond preparation:

- The ponds embankments were raised and repaired properly in the broken places.
- Pond dikes were repaired.
- All kinds of aquatic vegetation (floating, emergent, submerged and spreading) were removed manually.
- Liming was done at the rate of 1 kg per decimal. Lime was mixed with water and kept overnight and distributed on the pond surface the next morning.
- After 3 days of liming, ponds was filled with adjacent surface water and fertilized one week prior to stocking (200 g Urea/dec; 100 g TSP/dec).

Plate 7. Application of lime

Plate 8. Application of rotenone

2.c. Experimental design

Three (3) categories of carp species (surface feeder: *Gibelion catla*, *Hypophthalmicthys molitrix*; column feeder: *Labeo rohita*; bottom feeder: *Cirrhinus cirrhosus* and *Cyprinus carpio*) combinations were used for the experiment.

The experiment was consisted of 3 treatments, each with 3 replications as follows:

Treatment	Surface feeder	Column feeder	Bottom feeder
SC-$S_{30}C_{40}B_{30}$	30%	40%	30%
SC-$S_{40}C_{30}B_{30}$	40%	30%	30%
SC-$S_{35}C_{35}B_{30}$	35%	35%	30%

2.d. Stocking density and stocking of carp fishes

After pond preparation, the carp fishes were collected from Jashore and stocked in all experimental ponds by maintaining standard procedure. The stocking density was 10 individual/decimal. The average weight of carp fishes was145g.

Plate 9. Stocking of carp.

2.e. Feeding strategy

Artificial feed with 25% protein were fed for carp fishes**.** The feed was supplied 3% of fish body weight during the experiment. Fishes were sampled monthly to assess the growth and to adjust the feeding ration. Half of the ration was supplied at 9.00 am and remaininghalf was supplied at 3.00 pm. The feeding was done directly without any feeding trays.

Plate 10.Feed application

2.f. Water quality monitoring

The physico-chemical parameters of water in ponds viz. water temperature (°C), pH, dissolved oxygen(mg/l), alkalinity(mg/l), nitrate (mg/l), ammonia-nitrogen (mg/l), CO_2 (mg/l), TDS (mg/l) and plankton concentration were monitored monthly as per standard methods. Water temperature,dissolved oxygen, pH,alkalinity, Total Dissolved Solids (TDS and free carbon dioxide was determined with the help of HQ40D, HACH Multi meter, USA. Ammonia-nitrogen and nitrate were determined by FF2, HACH kit, USA. Plankton concentration in water was also determined with the help of Sedwick-Rafter (S-R) cell S50 counter under the biological microscope (EuromexMicroblue series, Holland).

Plate 11. Determination of physical parameters.

Plate 12. Determination of chemical parameters.

2.g. Fish growth performances

The fishes were sampled at fortnightly intervals to assess the growth rate of carp fishes in the experimental ponds. At least 10% of the stocked fishes were caught for each sampling in each experimental pond using seine net.

All growth parameters were used as following formula:

Initial weight (g) = Weight of fish at stock
Final weight (g) = Weight of fish at harvest
Weight gain (g) = [Mean final weight (g) – Mean initial weight (g)]
SGR (%/day) = [*ln* (Final weight) – *ln* (Initial weight)] ⁄Culture period in days] ×100
Survival rate (%) = [Number of fish harvested ⁄ Number of fish stocked] × 100
Gross yield = No. of fish caught × Average final weight
Net Yield = No. of fish caught × Average weight gained

Plate 13. Harvested carps.

2.h. Economics analysis

An economic analysis was performed to estimate the net benefit and benefit cost ratio (BCR) from different treatments. The cost of leasing ponds was not included in the total cost. The net benefit and benefit cost ratios (BCR) were calculated using the following formula:

Net benefit = Total revenue (Tk.) - Total cost (Tk.)

$$\text{BCR} = \frac{\text{Total revenue}}{\text{Total cost}}$$

The overall economics of different treatments were calculated on the basis of the expenditure incurred and the total return from the selling price of fish. All the expenditures and selling price of harvested fish were based on local market prices. The cost of labor, rotenone, lime, fertilizer, fish fingerling (including transportation) and commercial pellet feed was estimated. The interest rate on operating capital was estimated at the rate of 10% per annum for the duration of the culture period. At the end of the research, fishes were sold in a local market and the return was calculated. Values shown reflect combined data of all replicates within each treatment and returns were based on per hectare of fish production.

2.i. Statistical analysis

All numerical data are expressed as mean ± SD (standard deviation). For the statistical analysis of the data, Duncan's Multiple Range Test (DMRT) was done by using the SPSS (Statistical Package for Social Science, version 20.0) (SPSS Inc., Chicago, Illinois, USA) at the 95% confidence level. Microsoft excel 2010 was also used for data processing and analysis.

3. Exp- 2: Species suitability for farming of SIS in homestead ponds under coastal area

This experiment was performed on species suitability for farming of SIS fishes in homestead ponds under coastal areas of Bangladesh between July 2018 and March 2019.

3.a. Pond management

The experiment was conducted using a completely randomized design in nine (9) homestead farmer's ponds in the coastal region of Bangladesh those located at Anipara and Kathalpara village under Chakamaiya union in Kalaparaupazilla of Patuakhali. Most of the farmer's ponds in the coastal area were irregular shaped with low water depth. All ponds were prepared as per standard pond preparation protocol for grow-out pond.

3.b. Experimental design

Three treatments were conducted in this study having three replicates each. Walking catfish (*Clariasbatrachus*) in SP-Magur, stinging catfish (*Heteropneustes fossilis*) in SP-Shing, and Gangetic *Mystus* (*Mystus cavasius*) in SP-Gulsha were stocked at the rate of 150 fishes/decimal (37,050 fishes/ha) as SIS species. The mean stocking weight of *C. batrachus*, *H. fossilis*, and *M. cavasius*was 0.70 ± 0.00g, 0.76 ± 0.00 g, and 0.71 ± 0.00 g, respectively. SIS species were stocked in polyculture with carp species in homestead ponds where stocking density of carps were 2, 1, and 1 fish per decimal of Silver carp (*H. molitrix*), Catla (*G. catla*), and Rohu (*L. rohita*), respectively. All carp fishes and SIS species were collected from Jashore and Chanchalmatshya hatchery at Bauphal in Patuakhali, respectively.

Plate 14. Stocking of SIS.

3.c. Feeding management

Artificial feed containing 35% and 25% protein content were fed for SIS and carp fishes, respectively. The proximate composition of SIS feed was determined by using a standard AOAC method. Feeding began immediately after stocking of SIS and carp fishes. Artificial feeding for SIS species was done at the rate of 2 to 10% of fish body weight (started at the rate of 10% for the three months, 3% for the next two months, 2% for the next two months in winter season, and 3% of fish body weight for the final 2 months). On the contrary, artificial pellet feed for carps as co-species with SIS was done at the rate 3% of fish body weight and 2% fish feed provided only during in winter season. Fish were fed artificial feed twice a day at 9:00 am and 5:00 pm and the quantity of feed was adjusted fortnightly according to the total biomass of fish obtained from the sampling as part of monitoring fish growth.

3.d. Water quality monitoring

Water temperature (°C), dissolved oxygen (mg/l), pH and Total Dissolved Solids (TDS) (mg/l) were determined monthly by HQ 40D Multimeter. Free carbon dioxide (mg/l), ammonia-nitrogen (mg/l), nitrate- nitrogen (mg/l) and alkalinity (mg/l) were measured monthly by HACH kit (FF2, USA). Monthly plankton nos. in water was determined as per standard method.

3.e. Fish growth performances

All growth parameters were used as following formula:

Initial weight (g) = Weight of fish at stock
Final weight (g) = Weight of fish at harvest
Weight gain (g) = [Mean final weight (g) – Mean initial weight (g)]
SGR (%/day) = [*ln* (Final weight) – *ln* (Initial weight)] /Culture period in days] ×100
Survival rate (%) = [Number of fish harvested / Number of fish stocked] × 100
Gross yield=No. of fish caught × Average final weight
Net Yield= No. of fish caught × Average weight gained

Plate 15. Harvested Shing

Plate 16. Harvested Gulsha

Plate 17. Harvested Magur.

3.f. Economics analysis

The net benefit and benefit-cost ratio (BCR) were calculated using the following formula:

Net benefit = Total revenue (Tk.) - Total cost (Tk.)
Benefit-Cost Ratio (BCR) = Total revenue (Tk.) / Total investment (Tk.)

3.g. Statistical analysis

All numerical data are expressed as mean ± SD (standard deviation). For the statistical analysis of the data, Duncan's Multiple Range Test (DMRT) was done by using the SPSS (Statistical Package for Social Science, version 20.0) (SPSS Inc., Chicago, Illinois, USA) at the 95% confidence level. Microsoft excel 2010 was also used for data processing and analysis.

10.3.1. Methodology followed in second year (2019) ccomponent 1 (RU)

Two separate experiments (stocking density optimization in carp fattening and SIS-carp farming) were conducted in 2019.

1. Exp 2. Stocking density optimization in carp fattening

1.a.Selection of fish pond

A total of 18 ponds for experiments on carp fattening (mean area and depth of the ponds varied from 1.38±0.04 to 1.39±0.03 ha and 1.76±0.02 to 1.77±0.01m, respectively in Paba and that of 0.42±0.01 to 0.43±0.01ha and 1.65±0.03 to1.69±0.01m, respectively in Tanore) and another 18 ponds for SIS-carp farming (mean area and depth of the ponds varied from 0.04±0.00 to 0.05±0.00 ha and 1.35±0.02 to1.36±0.03 m, respectively in Paba and that of 0.037±0.00 to 0.040±0.00 ha and 1.30±0.01 to1.31±0.02 m, respectively in Tanore) were selected from the study areas (Fig1).

1.b. Experimental design

Stocking density (fishes/ha) of carp was optimized for fattening under three treatments (T_1: 2470; T_2: 3705; and T_3: 4940) and that of SIS fish (*C. batrachus*) was optimized for SIS-carp farming under three treatments (T_1: 37,050; T_2: 74,100; and T_3: 111,150). Species combination (40% surface feeder, 30% column feeder and 30% bottom feeder) was same for all the treatments of carp fattening experiment and co-species (*H. molitrix*-494/ha, *G. catla*-247/ha and *L. rohita*-247/ha) were same for all the treatments of SIS-carp farming experiment. Treatments were replicated thrice for the experiments. Fish growing period (July to December, 2019) was same for both experiments.

1.c. Pond management

Aquatic weeds form all the experimental ponds were removed manually (Plate 1). Unwanted fishes and other species were also removed through repeated netting. Overwintered carp seeds were used for stocking in fattening ponds whereas seeds of SIS fishes were shifted from nursery rearing to farmer managed grow out ponds for stocking (Plate 2). Lime and ash treatment in ponds under drought prone area was done after Hossain (2011) (Plate 1). Guideline for GAP aspects was followed after DoF (2012) and no organic manure was used except limited use of inorganic fertilizers. Fishes were fed (twice daily) with supplementary feed (25% protein content for carp fattening and 35% protein content in SIS fish farming) (Plate 2). Frequent field visits were also made for monitoring the pond management under different experiments (Plate 4).

1.d. Monitoring of water quality, fish growth and GAP aspects

Water quality parameters of the experimental ponds were monitored between 09:00 AM to 10:00 AM in each month (Plate 3).Fortnightly sampling was done for monitoring fish growth and adjusting the feeding ration (Plate 3). Growth and yield were calculated after Brett and Groves (1979). Before conducting the experiments (especially for carp fattening), pond water and fish feed samples were collected and heavy metals like lead and cadmium contents were determined through AAS technique. As a part of GAP aspects monitoring, pathogenic microbial load was also enumerated monthly in soil and water after FDA (2002).

1.e. Exploring the economics of fish farming

Total cost (including fixed and variable costs), total return, net benefit and cost benefit ratio (CBR) were calculated after Shang (1990) to explore the economics of fish farming under different treatments of the experiments on both carp fattening and SIS-carp farming in ponds.

1.f. Data analyses

Experimental data on water quality, fish growth and yield, economics of fish farming and GAP aspects were subjected to one way ANOVA (Analysis of Variance) using computer software SPSS (Statistical Package for Social Science). The mean values obtained under different treatments of the experiments were also compared to see the significant difference from the DMRT (Duncan Multiple Range Test) after Gomez and Gomez (1984). When a main effect was significant, the ANOVA was followed by Duncan Multiple Range Test (DMRT) at 5% level of significance. The percentages data were analyzed using arcsine-transformed data. All data were expressed as mean ± standard error (SE).

10.3.2. Methodology followed in second year (2019) by ccomponent 2(PSTU)

1. Exp 3: Optimization of stocking density for carp fattening in ponds under coastal area

1.a. Stocking of fish

Based on the suitable species combination such as surface feeder-35%, column feeder -35% and bottom feeder-30% from 1st year experiment, 3 treatments were used for determining suitable stocking densities, each with 3 replications as follows:

SD-10: 2470 fishes/ha (10 fishes/decimal)
SD-15: 3705 fishes/ha (15 fishes/decimal)
SD-20: 4940 fishes/ha (20 fishes/decimal)

Carp fishes such as Silver carp, Catla, Rui, Mrigal and common carp were stocked in the experimental ponds and the average initial weight was 426 g.

1.b. Stocking of fish

Based on the suitable species combination such as surface feeder-35%, column feeder -35% and bottom feeder-30% from 1st year experiment, 3 treatments were used for determining suitable stocking densities, each with 3 replications as follows:

SD-10: 2470 fishes/ha (10 fishes/decimal)
SD-15: 3705 fishes/ha (15 fishes/decimal)
SD-20: 4940 fishes/ha (20 fishes/decimal)

Carp fishes such as Silver carp, Catla, Rui, Mrigal and common carp were stocked in the experimental ponds and the average initial weight was 426 g.

Plate 18. Stocking of carps.

1.c. Feeding strategy

Artificial feed with 25% protein were fed for carp fishes**.** The feed was supplied 3% of fish body weight at the beginning of the experiment. Fishes were sampled monthly to assess the growth and to adjust the feeding ration. Half of the ration was supplied at 9.00 am and remains half was supplied at 4.00 pm. The feeding was done directly without any feeding trays

Plate 19. Feed application.

1.d. Water quality monitoring

Water temperature (°C), dissolved oxygen (mg/l), pH and Total Dissolved Solids (TDS) (mg/l) were determined monthly by HQ 40D Multimeter. Free carbon dioxide (mg/l), ammonia-nitrogen (mg/l), nitrate- nitrogen (mg/l) and alkalinity (mg/l) were measured monthly by HACH kit (FF2, USA). Plankton concentration in water was determined as per standard method in monthly.


Plate 20. Water quality analysis.

1.e. Fish growth performances

All growth parameters were used as following formula:

Initial weight (g) = Weight of fish at stock
Final weight (g) = Weight of fish at harvest
Weight gain (g) = [Mean final weight (g) – Mean initial weight (g)]
SGR (%/day) = [*ln* (Final weight) – *ln* (Initial weight)] /Culture period in days] ×100
Survival rate (%) = [Number of fish harvested / Number of fish stocked] × 100
Gross yield=No. of fish caught × Average final weight
Net Yield= No. of fish caught × Average weight gained


Plate 21. Harvested carps.

1.f. Economics analysis

The net benefit and benefit-cost ratio (BCR) were calculated using the following formula:

Net benefit = Total revenue (Tk.) - Total cost (Tk.)
Benefit-Cost Ratio (BCR) = Total revenue (Tk.) / Total investment (Tk.)

1.g. Statistical analysis

All numerical data are expressed as mean ± SD (standard deviation). For the statistical analysis of the data, Duncan's Multiple Range Test (DMRT) was done by using the SPSS (Statistical Package for Social Science, version 20.0) (SPSS Inc., Chicago, Illinois, USA) at the 95% confidence level. Microsoft excel 2010 was also used for data processing and analysis.

2. Exp 4: Optimization of stocking density for farming of SIS fishes in homestead ponds under coastal area

1.a. Experimental design

Based on the suitable species of SIS fish (Magur) from 1st year experiment, 3 treatments were used for determining suitable stocking densities, each with 3 replications as follows:

SD-150: 37,050 fishes/ha (150 fishes/decimal)
SD-300: 74,100 fishes/ha (300 fishes/decimal)
SD-450: 111,150 fishes/ha (450 fishes/decimal)

Magur were stocked in freshwater ponds with co-species carp and whereas carp stocked at Silver carp -2/decimal, Catla -1/decimal and Rui -1/decimal.

Plate 22. Stocking of SIS.

1.b. Water quality monitoring

Water temperature (°C), dissolved oxygen (mg/l), pH and Total Dissolved Solids (TDS) (mg/l) were determined monthly by HQ 40D Multimeter. Free carbon dioxide (mg/l), ammonia-nitrogen (mg/l), nitrate- nitrogen (mg/l) and alkalinity (mg/l) were measured monthly by HACH kit (FF2, USA). Plankton concentration in water was determined as per standard method in monthly.

1.c. Feeding management

Artificial feed containing 35% and 25% protein content were fed for SIS and carp fishes, respectively. Artificial feeding for SIS species was done at the rate of 2 to 10% of fish body weight. On the contrary, artificial pellet feed for carps as co-species with SIS was done at the rate 3% of fish body weight and 2% fish feed provided only during in winter season. Fish were fed artificial feed twice a dayat 9:00 am and 5:00 pm and the quantity of feed was adjusted fortnightly according to the total biomass of fish obtained from the sampling as part of monitoring fish growth.

1.d. Fish growth performances

All growth parameters were used as following formula:

Initial weight (g) = Weight of fish at stock
Final weight (g) = Weight of fish at harvest
Weight gain (g) = [Mean final weight (g) – Mean initial weight (g)]
SGR (%/day) = [*ln* (Final weight) – *ln* (Initial weight)] ⁄Culture period in days] ×100
Survival rate (%) = [Number of fish harvested ⁄ Number of fish stocked] × 100
Gross yield=No. of fish caught × Average final weight
Net Yield= No. of fish caught × Average weight gained


Plate 23. Harvested magur.

1.e. Economics analysis

The net benefit and benefit-cost ratio (BCR) were calculated using the following formula:

Net benefit = Total revenue (Tk.) - Total cost (Tk.)
Benefit-Cost Ratio (BCR) = Total revenue (Tk.) / Total investment (Tk.)

1.f. Statistical analysis

All numerical data are expressed as mean ± SD (standard deviation). For the statistical analysis of the data, Duncan's Multiple Range Test (DMRT) was done by using the SPSS (Statistical Package for Social Science, version 20.0) (SPSS Inc., Chicago, Illinois, USA) at the 95% confidence level. Microsoft excel 2010 was also used for data processing and analysis.

10.4.1. Methodology followed in third year (2020) ccomponent 1 (RU)

A total of four experiments/studies (two experiments on feed suitability for carp fattening and SIS-carp farming, one on the effect of loading densities on water quality and fish survival during live fish transportation and another one on organoleptic study of the cooked fishes produced under carp fattening) were conducted in 2020.

1. Feed suitability experiments

1.a. Selection of fish ponds

Ponds were selected both for feed trials (carp fattening and SIS-carp farming) and sample collection for organoleptic study. A total of 18 ponds for carp fattening (mean area and depth of the ponds varied from 1.37±0.03 to 1.41±0.04 ha and 1.69±0.02 to 1.72±0.02m, respectively in Paba and that of 0.41±0.01 to 0.42±0.01ha and 1.68±0.01 to1.72±0.02m, respectively in Tanore) and another 18 ponds for SIS-carp farming (mean area and depth of the ponds varied from 0.04±0.00 to 0.05±0.00 ha and 1.35±0.04 to1.40±0.03 m, respectively in Paba and that of 0.039±0.00 to0.040±0.01 ha and 1.32±0.02 to1.34±0.03 m, respectively in Tanore) were selected from the study areas. In case of organoleptic study, a total of 9 ponds (mean area, depth and organic matter content of the ponds varied from0.61±0.12 to 1.06±0.33ha, 1.63±0.02 to 1.69±0.03m, and 1.04±0.25 to 1.93±0.04%, respectively) were selected from Paba and Tanore upazilas (Fig1).

1.b. Experimental design

Feed suitability was determined under three treatments (T_1: regular feeding of 100% factory feed; T_2: regular feeding of 70% factory feed; and T_3: restricted feeding once per week of 70% factory feed) for carp fattening and SIS-fish farming through two separate experiments. Treatments were replicated thrice for the experiments. Fish growing period (July- to December, 2020) was same for the experiments. Two more experiments like live fish transportation (March-June, 2020) under three treatments of loading densities (kg fish/ton water) in truck (T_1: 80; T_2: 100; and T_3: 120) and organoleptic study (October, 2020) under three treatments of carp fattening management (T_1: inorganic fertilizers, feed and inclusion of silver carp under GAP management; T_2: organic and inorganic fertilizers, feed and inclusion of silver carp; and T_3: organic and inorganic fertilizers, feed and exclusion of silver carp) were also conducted. Each treatment of the experiments had three replications.

1.c. Pond management

Aquatic weeds form all the experimental ponds were removed manually (Plate 1). Unwanted fishes and other species were also removed through repeated netting. Overwintered carp seeds were used for stocking in fattening ponds whereas seeds of SIS fishes were shifted from nursery rearing to farmer managed grow out ponds for stocking (Plate 2). Lime and ash treatment in ponds under drought prone area was done after Hossain (2011) (Plate 1). Guideline for GAP aspects was followed after DoF (2012) and no organic manure was used except limited use of inorganic fertilizers. Fishes were fed (twice daily) with supplementary feed (25% protein content for carp fattening and 35% protein content in SIS fish farming) (Plate 2). Frequent field visits were also made for monitoring the pond management under different experiments (Plate 4).

1.d. Monitoring of water quality, fish growth and GAP aspects

Water quality parameters of the experimental ponds were monitored between 09:00 AM to 10:00 AM in each month (Plate 3). Fortnightly sampling was done for monitoring fish growth and adjusting the feeding ration (Plate 3). Growth and yield of fishes were calculated after Brett and Groves (1979). Before conducting the experiments (especially for carp fattening), pond water and fish feed samples were collected and heavy metals like lead and cadmium contents were determined through AAS technique. As a part of monitoring the GAP aspects, pathogenic microbial load was also enumerated in soil, water and fish after FDA (2002).

2. Study on live fish transportation

2.a. Duration and location of study

The study was conducted during March to June, 2020 with focus on transportation of live fishes (carps produced under fattening)from Parila of Paba upazila of Rajshahi district, Bangladesh. There are carp fattening practices in this area and live fishes are transported to Dhaka and other parts of Bangladesh through more than hundred trucks during peak season. Usually fishes are loaded with high densities and are often prone to stress due to poor water quality while transportation in truck especially at distant places.

2.b. Experimental design

Present experiment evaluated the water quality and survival rate under three different treatments of loading densities (kg fish per ton of water) in truck (T_1: 80; T_2: 100; and T_3: 120). Treatments were replicated thrice. Start point (i.e., fish loading point at Parila of Paba upazila, Rajshahi), destination or end point (i.e., fish unloading point at New market area of Dhaka city, Dhaka), harvesting, depuration, loading of fishes, aeration and water exchange techniques were similar for all the treatments.

2.c. Pre-loading management

Fishes were subjected to 12 hours starvation in fattening ponds before harvesting. Fishes of desired species and sizes were harvested by netting from the ponds. Harvested fishes were then kept for 12 hours depuration in a conditioning tank (circular tank with pump water supply).

2.d. Loading of fishes in truck

After necessary depuration, fishes were taken from conditioning tank and loaded into truck (Plate 5). The cargo bed (4.9 m in length and 2.7m in width) of the truck was covered with a tarpaulin so as to hold water. Water level in the bed was maintained as 0.8m. A net was also placed at the top of the cargo bed so as to prevent the fishes from escaping. Fish loading was completed by evening in order to transport the fishes during night under lower temperature.

2.e. Aeration and water exchange

Trucks were provided with aeration facilities to the fishes in cargo bed with the help of a 4 Hp pump. Water exchange for the cargo bed was done once at Sirajgonj to compensate the water loss during transport.

2.f. Monitoring water quality and fish survival rate

Monthly monitoring was done for the study of important water quality parameters (temperature, pH, dissolved oxygen and ammonia-nitrogen at start point between 5:00 and 6:00 pm and at end point between 5:00 and 6:00 am) and survival rate of fishes (at end point between 5:00 and 6:00 am) (Plate 5).

3. Organoleptic study for harvested carps

Fish samples (harvested carps) were collected during October, 2020 from three different management systems of carp fattening under three treatments. Three treatments of management in carp fattening in this study were T_1: using fertilizers (inorganic) and feed in fattening with inclusion of silver carp; T_2: using fertilizers (organic and inorganic) and feed in fattening with inclusion of silver carp; and T_3: using fertilizers (organic and inorganic) and feed in fattening with exclusion of silver carp. Species combination; stocking density, harvest size and cooking of the harvested carps are same under different treatments. A score sheet was purposively developed for evaluating the taste, odor and texture of the cooked fishes under different treatments by the panel members (a total of 60 members, 20 members for each treatment group). A briefing was given to the panel members (Plate 6) stating the objectives of the study and guidelines for assessment of the cooked fishes in terms of sensory characteristics after Huss (1995).

4. Exploring the economics of fish farming

Total cost (including fixed and variable costs), total return, net benefit and cost benefit ratio (CBR) were calculated after Shang (1990) to explore the economics of fish farming under different treatments of the experiments on both carp fattening and SIS-carp farming in ponds.

5. Data analyses

Data on organoleptic study was subjected to descriptive analysis. Experimental data on water quality, fish growth and yield, economics of fish farming and GAP aspects were subjected to one way ANOVA (Analysis of Variance) using computer software SPSS (Statistical Package for Social Science). Similarly experimental data on water quality and survival rate of fish under live fish transportation study were also subjected to one way ANOVA. The mean values obtained under different treatments of the experiments were also compared to see the significant difference from the DMRT (Duncan Multiple Range Test) after Gomez and Gomez (1984). When a main effect was significant, the ANOVA was followed by Duncan Multiple Range Test (DMRT) at 5% level of significance. The percentages data were analyzed using arcsine-transformed data. All data were expressed as mean ± standard error (SE).

6. Capacity building and technology dissemination

Module based group discussion (with focus on pond management, GAP and problem solving aspects) was conducted for increasing the capacity of the farmers (Plate 6). Experimental findings were also shared through developing leaflets and scientific paper and conducting technology based field day and workshop (Plate 6).

10.4.2. Methodology followed in third year (2020) by component 2 (PSTU)

1.Exp 5: Effects of supplementary feeds on the production and economics of carp fattening in ponds under coastal area

1.a. Location

The experiments were conducted in farmer's ponds. The research site was selected at Nillganjat Kalapara upazilla under Patuakhali District.

1.b. Design of trial

The experiment was conducted with 3 treatments and each with 3 replications. Three treatments were designated with:

Factory$_{100\%}$: regular feeding of 100% factory feed.
Factory$_{70\%}$: regular feeding of 70% factory feed and 30% home-made feed.
Restricted: restricted feeding (no feeding once per week) of 70% factory feed and 30% home-made feed.

1.c. Pond Preparation

Ponds were renovated with respect to dykes, depth, slope, bottom elevation, supply and drainage facilities. Rotenone powders were applied for controlling predatory or weed fishes from the experimental ponds. These ponds were limed at a rate of 1 kg/decimal. Ponds were filled with water up to 1.2 m. After 7 days of liming, inorganic fertilizer was applied i.e. 200 g urea and 100 g TSP in 1 decimal pond area.

1.d. Stocking of carps

Carp species were collected from local nursery located at Kalapara, Patuakhali and stocked in the experimental ponds.

Plate 24. Stocking of carps.

1.e. Feeding of carp

Home-made and factory made feed with 25% protein were fed for carp fishes. Feed was adjusted fortnightly according to the total biomass of fish obtained from the sampling as part of monitoring fish growth.

Plate 25. Feeding of carps.

1.f. Measurement of water quality parameters

Water temperature (°C), dissolved oxygen (mg/l), pH and Total Dissolved Solids (TDS) (mg/l) were determined monthly by HQ 40D Multimeter. Free carbon dioxide (mg/l), ammonia-nitrogen (mg/l), nitrate- nitrogen (mg/l) and alkalinity (mg/l) were measured monthly by HACH kit (FF2). Monthly plankton concentration in water was determined as per standard method.


Plate 26. Water quality analysis.

1.g. Estimation of growth, yield and survival of fish

Fish were harvested at the end of the experiment in February, 2021. During stocking and harvest, all fish were weighed and counted pond wise following formula to determine fish yield:

Average final weight= Average final weight – Average initial weight

$$\text{Specific growth rate (SGR, \% bwd}^{-1}\text{)} = \frac{\text{Ln final weight - Ln initial weight}}{\text{Culture Period}} \times 100$$

Survival rate (%) = (No. of fish caught/ No. of fish released) ×100
Gross yield=No. of fish caught × Average final weight
Net Yield= No. of fish caught × Average weight gained


Plate 27. Harvested carps.

10.5. GAP aspects

10.5.a. Determination of heavy metals

Water, sediment and fish samples were collected from the experimental ponds. Assessment of two (lead and cadmium) heavy metal contents of the samples was performed with Atomic Absorption Spectrophotometer (AA-7000,Shimadzu, Japan) at Soil Science Division, Bangladesh Agricultural Research Institute, Gazipur, Bangladesh.

10.5.b. Pathogenic microbial load

Bacteriological study was conducted by following Standard Plate Count (SPC) method (AOAC 2007). Standard plate count expressed as colony forming units per gram (cfu/g) was determined by using consecutive decimal dilution technique using spread plate method. One milliliter of each homogenate (fish, sediment and water stock solution) was transferred with a micropipette to test tube containing 9 ml of physiological saline in order to get 10^{-1} dilution of original sample solution. Using the similar process several dilutions of 10^{-2} to 10^{-5} was made for fish, sediment and water samples. Aliquots of 0.1 ml of the serial dilutions was pipetted out and transferred aseptically to the agar plates in triplicate using the spread plate method. The sample was then spread homogenously and carefully by sterile flamed L-shaped glass rod. The plates were incubated at 35°C for 48 hours in an inverted position. After 48 hours of incubation colonies observed on the media were counted. Plates containing 30-300 colonies were used to calculate bacterial load results, recorded as cfu per unit of sample by using following formula:

For sediment/water sample: Cfu/ml = No. of colonies in Petridish × 10 × dilution factor
For fish sample:

$$\text{Cfu/g} = \frac{\text{No. of colonies in Petridish} \times 10 \times \text{dilution factor} \times \text{volume of total stock solution}}{\text{Wt. of fish sample (g)}}$$

10.5.c. Economic analysis

An economic analysis was performed to estimate the net benefit and benefit cost ratio (BCR) from different treatments. The net benefit and benefit cost ratios (BCR) were calculated using the following formula:

Net benefit = Total revenue (Tk.) - Total cost (Tk.)

$$\text{BCR} = \frac{\text{Total revenue}}{\text{Total cost}}$$

10.5.d. Statistical analysis

For the statistical analysis of the data, Duncan's Multiple Range Test was done by using the SPSS (Statistical Package for Social Science) version-20.0. Significance was assigned at the 0.5% level of confidence and Microsoft excel 2010 was also used for data processing and analysis.

2. Exp 6: Effects of supplementary feeds on the production and economics SIS fish (Magur, *Clarias batrachus*) farming in homestead ponds under coastal area

2.a. Location

The experiments were conducted in farmer's ponds at Kalapara upazilla under Patuakhali

2.b. Design of trials

The experiment was conducted with 3 treatments and each with 3 replications. Three treatments were designated with:

$Factory_{100\%}$: regular feeding of 100% factory feed.
$Factory_{70\%}$: regular feeding of 70% factory feed and 30% home-made feed.
Restricted: restricted feeding (no feeding once per week) of 70% factory feed and 30% home-made feed.

Magur were stocked in the experimental ponds with co-species carp and whereas carp stocked at Silver carp -2/decimal, Catla -1/decimal and Rui -1/decimal.

2.c. Pond Preparation

Ponds were renovated with respect to dykes, depth, slope, bottom elevation, supply and drainage facilities. Rotenone powders were applied for controlling predatory or weed fishes from the experimental ponds. These ponds were limed at a rate of 1 kg/decimal. Ponds were filled with water up to 1.2 m. After 7 days of liming, inorganic fertilizer was applied i.e. 200 g urea and 100 g TSP in 1 decimal pond area.

2.d. Stocking of magur

Magur species were collected from Chanchal Matshya Hatchery, Bauphal, Patuakhali and stocked in the experimental ponds.

Plate 28. Stocking of magur.

2.e. Feeding of Magur

Home-made and factory-made feed with 30% protein were fed for Magur. Feed was adjusted fortnightly according to the total biomass of fish obtained from the sampling as part of monitoring fish growth.

2.f. Measurement of water quality parameters

Water temperature (°C), dissolved oxygen (mg/l), pH and Total Dissolved Solids (TDS) (mg/l) were determined monthly by HQ 40D Multimeter. Free carbon dioxide (mg/l), ammonia-nitrogen (mg/l), nitrate- nitrogen (mg/l) and alkalinity (mg/l) were measured monthly by HACH kit (FF2). Monthly plankton concentration in water was determined as per standard method.

2.g. Fish growth performances

All growth parameters were used as following formula:

Initial weight (g) = Weight of fish at stock
Final weight (g) = Weight of fish at harvest
Weight gain (g) = [Mean final weight (g) – Mean initial weight (g)]
SGR (%/day) = [*ln* (Final weight) – *ln* (Initial weight)] /Culture period in days] ×100
Survival rate (%) = [Number of fish harvested / Number of fish stocked] × 100
Gross yield = No. of fish caught × Average final weight
Net Yield = No. of fish caught × Average weight gained


Plate 29. Harvested magur.

2.h. Economic analysis

An economic analysis was performed to estimate the net benefit and benefit cost ratio (BCR) from different treatments. The net benefit and benefit cost ratios (BCR) were calculated using the following formula:

Net benefit = Total revenue (Tk.) - Total cost (Tk.)

$$BCR = \frac{\text{Total revenue}}{\text{Total cost}}$$

2.i. Statistical analysis

For the statistical analysis of the data, Duncan's Multiple Range Test was done by using the SPSS (Statistical Package for Social Science) version-20.0. Significance was assigned at the 0.5% level and Microsoft excel 2010 was also used for data processing and analysis.

10.6. Capacity building and technology dissemination

Training on carp fattening technology and culture of Magur was conducted for increasing the capacity of the fish farmers. Farmers group discussion was also (with focus on pond management, GAP and problem solving aspects) conducted for increasing the capacity of the farmers. Experimental findings were shared through developing leaflets and conducting technology based field day. Fish farmers were visited Rajshahi areas for gathering knowledge on carp fattening. Different experts from BARC and RU visited sub-projects areas and farmers were benefited through sharing experiences with them.

Plate 30. Training on carp fattening and magur.


Plate 31. Group discussion on carp fattening.

Plate 32. Field day on carp fattening.

Plate 33. Visit by PIU-BARC, NATP-2 team

Plate 34. Component 2 visited research area of Componen1 (Rajshahi)

11. Results and discussion (Combined)

11.1. Survey findings on carp fattening by Component 1 (RU)

The survey findings (in terms of profile of the farmers and ponds, production and economics of carp fattening and problems faced by the farmers) are shown in Tables 1 to 7.

1.a. Farmer's profile

A total of 36 farmers (100% male farmer) were selected (18 farmers from Paba upazila and 18 farmers from Tanore upazila) in the study areas. The profile of the farmers in terms of age, education, training and household income is shown in Table 1 to 4. More than 50% of the farmers were found between the age of 25 and 35 years in Paba and between 31 and 40 years in Tanore upazila. No illiterate farmer was found in both the sites. Almost 50% farmers reported that they received training on aquaculture in Paba whereas only 16.67% farmers reported to have the aquaculture training in Tanore. A few number of farmer (05.56% in Tanore and 11.11% in Paba) reported to have the training on GAP (Good aquaculture practice) aspects towards safe fish production. Majority of the farmers were found with the monthly household income as above BDT 20,000.00.

1.b. Pond profile

The profile of the ponds in terms of area, depth and age is shown in Table 5. Mean values of area (ha), depth (m) and age (year) of the ponds varied from 00.64±0.07 (Tanore) to 01.02±0.18 (Paba), 01.99±0.05 (Tanore) to 02.09±0.08 (Paba) and 10.56±1.29(Tanore) to 11.11±1.90 (Paba), respectively.

11.1.1. Production and economics of carp fattening

Fish production and economics (in terms of cost benefit ratio, CBR) of the carp fattening ponds are shown in Table 6. Mean fish production (kg/ha/yr) varied from 4713.28±77.21 (Paba) to4838.89±53.74 (Tanore). Mean CBR varied from 0.32±0.012 (Tanore) to 0.36±0.014 (Paba).

11.1.2. Problems faced by the farmers in carp fattening

A total of 11 major problems were identified during study (Table 7). Problems were mostly related to lack of low cost supplementary feed, lack of quality fish seed, water quality going bad (insufficient water, plankton bloom, oxygen shortage, mortality during high temperature, plankton crush and gas formation), occurrence of disease, lack of capital/credit for farming and finding no fair price of the harvested fishes.

11.1.3. Survey findings on fish farming (carp polyculture) in homestead ponds

The survey findings in terms of profile of the farmers and ponds, production and economics of carp polyculture and problems faced by the farmers are shown in Table 8 to 14.

1.a. Farmer's profile

A total of 36 farmers (100% women farmer) were selected (18 from Paba upazila and 18 farmers from Tanore upazila) in the study areas. The profile of the farmers in terms of age, education, training and household income is shown in Table 8 to 11. Majority of the farmers were found between the age of 26 and 30 years in Paba and between 31 and 35 years in Tanore upazila. Majority of the farmers were found with primary level (44.44%) education in Paba and with class eight (33.33%) in Tanore. Almost 100% farmers reported that they received no training on aquaculture in Paba whereas only 16.67% farmers reported to have the aquaculture training in Tanore. Almost 50% farmers were found with the monthly household income as bellow BDT 5,000.00 in Paba and 38.88% farmers were found with the monthly household income as BDT 5,001.00 to 10,000.00 in Tanore.

1.b. Pond profile

The profile of the ponds in terms of area, depth and age is shown in Table 12. Mean values of area (ha), depth (m) and age (year) of the ponds varied from 0.11±0.01 (Tanore) to 00.18±0.001

(Paba), 02.27±0.05 (Tanore) to 02.37±0.03 (Paba) and 29.44±2.62 (Tanore) to 33.05±1.52 (Paba), respectively.

11.1.4. Production and economics of fish farming in homestead ponds

Fish production and economics (in terms of cost benefit ratio, BCR) of the carp fattening ponds are shown in Table 13. Mean fish production (kg/ha/yr) varied from 2,895.11±75.32 (Tanore) to 3,164.72±82.92 (Paba). Mean BCR varied from 0.21±0.01 (Tanore) to 0.25±0.01 (Paba).

11.1.5. Problems faced by the farmers in homestead ponds

A total of 12 major problems were identified during study (Table 14). Problems were mostly related to lack of appropriate fish farming technology for homestead ponds, lack of low cost supplementary feed, lack of quality fish seed, water quality going bad (insufficient water, plankton bloom, oxygen shortage, mortality during high temperature and gas formation), no easy access to credit for farming and occurrence of disease.

The size of the ponds as reported by the respondents was comparatively larger for carp fattening. On the other hand, homestead ponds mostly used for carp polyculture were smaller in size. Since there are sufficient proven technologies both types of ponds are considered potentials for aquaculture in drought prone area. Findings almost agreed with Hossain *et al*. (2009) while working on public ponds and canals in drought prone area. Findings also agreed with Jahan *et al*. (2010) while addressing the use of homestead ponds in aquaculture towards food security. Existing carp fattening with lower profit margin and associated farming problems was not found attractive. Lack of training on GAP aspects was also noted in most cases of carp fattening towards safe fish production. Present survey findings indicated the necessity of improving the existing carp fattening in terms of suitable species, density and combination; use of quality seed and low cost feed; and practice of good management towards the sustainability of carp fattening in ponds. Similarly existing carp polyculture in homestead ponds was not also found attractive in terms of production, income and effective utilization of the ponds under drought prone area. In fact poor farmers of the homestead ponds were deprived of using potential technique like SIS fish farming due to the lack of sufficient efforts. Importance of SIS fish farming for the effective utilization of homestead ponds under drought prone area is well documented by Nabi *et al*. (2020). Thus present survey findings also indicated the necessity for inclusion of high valued SIS fishes to the existing farming practice towards the effective utilization of the homestead ponds. Pond aquaculture is differentiated between two main forms of ‘homestead pond culture’ and ‘entrepreneurial pond culture’ because the two have considerably different profiles with respect to their origins, species produced, size of operations, intensity of production, amount of capital investment, the socio-economic characteristics of producers, and the level of both primary on-farm employment and secondary employment in associated value chains (Belton *et al*. 2011). Present status of the fattening and homestead ponds with associated farming problems were almost agreed with Hossain (2011) addressing the regional aquaculture problems in ponds under drought prone barind area, with Khan *et al*. (2018) addressing the poor quality seed problem in aquaculture and with Talukder *et al*. (2017) mentioning high feed cost involvement in carp farming in ponds under drought prone area of Bangladesh. Therefore, it is necessary to improve the existing carp fattening with focus on GAP aspects and to introduce high valued SIS fish farming in homestead ponds under drought prone area of Bangladesh.

11.1.6. Findings from experiments on carp fattening in ponds

Major findings (in terms of water quality, fish growth and yield, economics and GAP aspects) of the carp fattening experiments conducted in Paba and Tanore upazilas are shown in Table 15 to 25.

11.1.7. Carp fattening in ponds of Paba upazila, Rajshahi

1.a. Water quality

Variations in the mean values of water quality parameters are shown in Table 15. Except temperature and pH, all the parameters varied significantly ($P < 0.05$) with the treatments.

1.b. Fish growth

Variations among the treatments in growth performances (in terms of initial weight, final weight, weight gain, SGR and survival rate) of fishes during culture period are shown in Table 1.16. Except, initial stocking weight, all the growth parameters varied significantly ($P < 0.05$) with the treatments in case of most of the species. In most cases, higher values of mean final weight of fishes were found with treatment T_2 (Surface feeder dominant treatment).

1.c. Fish yield

Variations in the fish yield under the treatments are shown in Table 17. All the treatments varied significantly ($P<0.05$) for the yield of different fish species. Treatment T_2 varied more significantly than other treatments during study. Fish yield with treatment T_2 was 16.17% higher than treatment T_1 and 5.93% higher than treatment $T_{3.}$

1.d. Economics of carp fattening

Variations in the mean values of cost, net benefit and CBR are shown in Table 18. No significant difference was found among the treatments for the mean values of total cost whereas net benefit and CBR varied significantly ($P < 0.05$) with the treatments. Feed was the major cost involving area (55.62-56.92% of the total cost) with the treatments. Apart from the feed, two other important factors like lease value (13.51-13.82%) and water addition (1.19-1.22% of the total cost) for the ponds increased the cost of fish production through carp fattening in drought prone area. Net benefit with treatment T_2 was 43.00% higher than treatment T_1 and 12.53% higher than treatment $T_{3.}$

11.1.8. Carp fattening in ponds of Tanore upazila, Rajshahi

1.a. Water quality

Variations in the mean values of water quality parameters are shown in Table 19. Except temperature, pH and alkalinity, all the parameters varied significantly ($P < 0.05$) with the treatments. Water transparency was found lowest with treatment T_1 that received lowest amount of surface feeder specially the silver carp.

1.b. Fish growth

Variations among the treatments in growth performances (in terms of initial weight, final weight, weight gain, SGR and survival rate) of fishes during culture period are shown in Table 20. Except, initial stocking weight, all the growth parameters varied significantly ($P < 0.05$) with the treatments in case of most of the species. Significantly higher mean values of Rui, Mrigal and Carpio with treatment T_2 indicated that appropriate number and combination of surface feeding carps favored the growth of column and bottom feeding carps in that treatment.

1.b. Fish yield

Variations in the fish yield under the treatments are shown in Table 21. All the treatments varied significantly ($P < 0.05$) for the yield of different fish species.TreatmentT_2 varied more significantly than other treatments during study. Fish yield with treatment T_2 was 20.48% higher than treatmentT_1 and 11.88% higher than treatmentT_3.

1.c. Economics of carp fattening

Variations in the mean values of cost, net benefit and BCR are shown in Table 22. Total cost, net benefit and BCR varied significantly ($P<0.05$) with the treatments. Feed was the major cost involving area (55.00-60.00%of the total cost) with the treatments. Apart from the feed, two other important factors like lease value (12.29-12.64%) and water addition (1.22-1.25%of the total cost) for the ponds are increasing the cost of fish production through carp fattening in drought prone barind area. Net benefit with treatmentT_2 was 51.89% higher than treatment T_1 and 27% higher than treatmentT_3.

11.1.9. GAP aspects of carp fattening ponds

GAP aspects in terms of pathogenic bacteria and heavy metal concentration are shown in Table 1.23-1.25. Bacterial load was found lower in water than that of the bottom soil (Table 23-24). Concentration of cadmium (0.016-0.025 ppm) was found higher than lead (0.003-0.007 ppm) during study (Table 25).

Water transparency was found lowest with treatment T_1 that received lowest amount of surface feeder specially the Silver carp. Present findings clearly indicates that Silver carp (with appropriate number in polyculture ponds) can play a significant role for improvement in water quality and it was reflected well while most of the parameters were found within suitable range for fish farming specially with treatment T_2. Comparatively higher clay turbidity in ponds under Tanore upazila is the common character of the fish ponds under barind area of Bangladesh (Hossain, 2011) and it is reflected well in this study while finding almost lower water transparency with the treatments. However, apart from the water transparency, most of the parameters were found within more or less suitable range for fish farming (Boyd, 1998). Water quality parameters recorded during the study period were more or less similar to the findings of Talukder *et al.* (2018) who worked on carp polyculture in ponds under drought prone barind area. This study strictly followed the GAP guidelines for the experimental ponds under all the treatments which ultimately reflected with the very lower concentration of heavy metal and bacteria recorded with the treatments. Actually quality of water determines the quality of the product as well as the success of aquaculture industry. There is a chance of degradation of the water quality through increased addition of the nutrients from different sources. Coliform is a good indicator for the presence of pathogenic bacteria in water. Some factors which may affect the concentration of this bacteria are the presence of wastewater and septic system, animal wastes, run-off, high temperature and nutrient-rich water. Some of the countries follow to keep an acceptable level of total coliform bacteria for aquaculture in freshwater as 100-5,000 MPN. Findings of the study indicated that the concentration of total coliform bacteria in pond water of both the sites was within the more or less acceptable range. The acute toxic concentrations of lead in different types of water are in the range of 10 to 100 mg/l for cyprinids. The maximum admissible lead concentration in water is 0.07 mg/l for cyprinids. For cyprinids, the maximum admissible cadmium concentration in water is 0.001 mg per litre and the acute lethal concentration of cadmium for different species of fish is from 2 to 20 mg/l. However, the toxic effects of these heavy metals are reduced by the increased level of alkalinity in water (FAO, 1993). Comparatively higher alkalinity obtained with the experimental ponds indicated poor or less toxic effects by heavy metals. The fish yield obtained with the treatments was higher than that of recorded by Talukder *et al* (2018). Higher yield of the present study might be due to the use of larger size and over wintered carps. Overwintering is a proven technique to obtain the fast growth of fish(Ali *et al*., 2003) and larger stocking size under lower density can help to obtain maximum fish biomass within shorter period of time(Grover *et al*., 2000). Overall findings indicated that treatment T_2 was found best in terms of water quality, growth, yield and economics of carp fattening in ponds of both Paba and Tanore upazilas. Findings clearly indicated that inclusion of appropriate number of surface feeding carp specially the silver carp not only improved the water quality but also favored the fish growth and thereby increased the total fish biomass and net profit. Role of a very efficient filter feeder like silver carp to improve the water quality and fish yield is also strongly documented by Milstein (1992) and Kadir *et al*. (2006). Findings also indicates that carp fattening is constrained by high feed cost (more than 50% of the total cost) and high lease value of the ponds (more than 12% of the total cost). Moreover, water addition cost (almost 1-2% of the total cost) is also increasing the total cost for fish production through carp fattening in drought prone area. Therefore, appropriate selection of species combination, stocking density and low cost feed application are important for the sustainability of this system. One of the limitation of the study was the use of similar (only one) stocking density with the treatments. Therefore, considering all these facts and figures, further research can be initiated with the optimization of stocking density for carp fattening ponds with emphasis on GAP aspects.

11.1.10. Findings of the experiments on SIS-carp farming in homestead ponds

Major findings (in terms of water quality, fish growth and yield and economics) of the SIS-carp farming experiments conducted in Paba and Tanore upazilas are shown in Table 26 to 33**.**

11.1.10.1. SIS-Carp farming in ponds of Paba upazila, Rajshahi

1.a.Water quality

Variations in the mean values of water quality parameters are shown in Table 26. No significant difference was found among the treatments for almost all the water quality parameters except ammonia-nitrogen (NH_3-N) and total dissolved solids (TDS).

1.b. Fish growth

Variations among the treatments in growth performances (in terms of initial stocking weight, final weight, weight gain, SGR and survival rate) of fishes during culture period are shown in Table 27. No significant difference was found among the treatments for the mean survival rates in case of most of carps but treatments varied significantly ($P<0.05$)for the same in case of SIS fishes. Treatment T_2 varied more significantly ($P<0.05$) than others for the mean final weight, weight gain and SGR in case of most of the species.

1.c. Fish yield

Variations in the fish yield under the treatments are shown in Table 28. All the treatments varied significantly ($p<0.05$) for the yield of SIS fishes whereas no significant difference was found among the treatments for the yield of carp species. TreatmentT_2 varied more significantly than other treatments for the total fish yield. Fish yield with treatmentT_2 was 20.93% higher than treatment T_1 and 68.32% higher than treatment $T_{3.}$

1.d. Economics of SIS-carp farming

Variations in the mean values of cost, net benefit and BCR are shown in Table 29. Treatments varied significantly ($P <0.05$) for the mean values of total cost, total return, net benefit and BCR. Feed was the major cost involving area with the treatments (13.63-46.31%). Net benefit with treatment T_2 was 24.97% higher than treatmentT_1 and 84.93% higher than treatment$T_{3.}$

11.1.11. SIS-carp farming in ponds of Tanore upazila, Rajshahi

1.a. Water quality

Variations in the mean values of water quality parameters are shown in Table 30. No significant difference was found among the treatments for almost all the water quality parameters. Comparatively lower value of water transparency was recorded with the treatments.

1.b. Fish growth

Variations among the treatments in growth performances (in terms of initial stocking weight, final weight, weight gain, SGR and survival rate) of fishes during culture period are shown in Table 31. No significant difference was found among the treatments for the mean survival rates in case of both SIS fishes and carps. Treatment T_2 varied more significantly ($P < 0.05$) than others for the mean final weight of SIS fish i.e. Magur was the best performing species during study.

1.c. Fish yield

Variations in the fish yield under the treatments are shown in Table 32. All the treatments varied significantly ($P<0.05$) for the yield of SIS fishes whereas no significant difference was found among the treatments for the yield of carp species. TreatmentT_2 varied more significantly than other treatments for the total fish yield. Fish yield with treatmentT_2 was 23.01% higher than treatment T_1 and 70.15% higher than treatment $T_{3.}$

1.d. Economics of SIS-carp farming

Variations in the mean values of cost, net benefit and BCR are shown in Table 33. Treatments varied significantly ($P<0.05$) for the mean values of total cost, total return, net benefit and BCR. Feed was the major cost involving area with the treatments (19.39-60.14%). Net benefit with treatmentT_2 was 25.24% higher than treatmentT_1 and 84.67% higher than treatment$T_{3.}$

There was minor variation in water quality especially for transparency and alkalinity values between the two sites. Comparatively higher turbidity (lower water transparency) and lower alkalinity recorded with Tanore site is the normal phenomenon of barind area (Hossain, 2011), however, mean water quality of the ponds under SIS-carp farming was more or less suitable for fish farming (Boyd, 1998). Among the SIS fishes used in this experiment, growth and yield performance of Gulsha was found very poor in both sites. Comparatively higher growth and yield performance with shing and Magur than that of Gulsha might be due to the effect of "individual size and metabolism". Gulsha is by born (or by nature) smaller than Shing or Magur at mature stage which requires more metabolism and produces less biomass. Almost 50% higher yield was obtained from Magur based carp farming than that of Gulsha based carp farming. In adult condition, the highest length is recorded as 45.7cm in *C. batrachus* and 30 cm each for *H. fossilis* and *M. cavasius* (DoF, 2018). Actually the fish with lower body size results higher metabolic activity and thus produces lower biomass (Boyd, 1998).Overall findings indicated that treatment T_2 was found best in terms of water quality, growth, yield and economics of SIS-carp farming in homestead ponds of both Paba and Tanore upazilas. One of the limitation of the study was the use of similar (only one) stocking density with the treatments. Therefore, considering all these facts and figures, further research can be initiated with the optimization of stocking density in Magur based carp polyculture in homestead ponds.

Table 1. Age of the farmers involved in carp fattening

Age group (Year)	Paba (N=18)		Tanore (N=18)	
	No. of farmer	% of farmer	No. of farmer	% of farmer
25-30	4	22.22%	0	00.00%
31-35	6	33.30%	5	27.77%
36-40	4	22.22%	5	27.77%
41-45	3	16.67%	5	27.77%
46-50	0	00.00%	2	11.11%
51-55	1	05.55%	1	05.55%

Table 2. Education of the farmers involved in carp fattening

Education level	Paba (N=18)		Tanore (N=18)	
	No. of farmer	% of farmer	No. of farmer	% of farmer
Illiterate	0	00.00	0	00.00
Primary	5	27.78	2	11.11
Class eight	3	16.67	6	33.33
SSC	2	11.11	5	27.78
HSC	2	11.11	4	22.22
Higher	6	33.33	1	05.56

Table 3. Training of the farmers involved in carp fattening

Training received on	Paba (N=18)		Tanore (N=18)	
	No. of farmer	% of farmer	No. of farmer	% of farmer
Aquaculture	9	50.00	3	16.67
GAP aspects	2	11.11	1	05.56

Table 4. Household income of the farmers involved in carp fattening

Monthly income (BDT)	Paba (N=18)		Tanore (N=18)	
	No. of farmer	% of farmer	No. of farmer	% of farmer
<5,000	0	00.00%	0	00.00%
5,001-10,000	0	00.00%	2	11.11%
10,001-15,000	2	11.11%	0	00.00%
15,001-20,000	1	05.55%	3	16.67%
>20,000	15	83.33%	13	72.22%

Table 5. Profile of the ponds under carp fattening

Aspects	Paba (N=18)			Tanore (N=18)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Area (ha)	00.14	02.80	01.02±0.18	00.27	01.33	00.64±0.07
Depth (m)	01.50	02.80	02.09±0.08	01.80	02.50	01.99±0.05
Age (Yrs)	03.00	40.00	11.11±1.90	02.00	22.00	10.56±1.29

Table 6. Production and economics (in terms of cost benefit ratio, CBR) of carp fattening

Aspects	Paba (N=18)			Tanore (N=18)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Fish production (kg/ha/yr)	3980.00	5200.00	4713.28±77.21	4389.00	5187.00	4838.89±53.74
CBR	0.24	0.44	0.36±0.014	0.23	0.39	0.32±0.012

Table 7. Major problems reported by the farmers in carp fattening

Sl. No.	Problems faced by the farmers	Paba (N=18)		Tanore (N=18)	
		No. of farmer	% of farmer	No. of farmer	% of farmer
1	Lack of low cost supplementary feed	18	100.00	17	94.44
2	Plankton bloom	17	94.44	16	88.89
3	Mortality during high temperature	16	88.89	15	83.33
4	Oxygen shortage	15	83.33	14	77.78
5	Insufficient water	14	77.78	18	100.00
6	Gas formation	13	72.72	11	61.11
7	No fair price of the harvested fishes	12	66.67	13	72.72
8	Lack of quality fish seed	10	55.56	09	50.00
9	Occurrence of disease	9	50.00	07	38.89
10	Plankton crush	8	44.44	08	44.44
11	Lack of capital/credit	7	38.89	06	33.33

Table 8. Age of the farmers involved in fish farming in homestead ponds

Age group (Year)	Paba (N=18)		Tanore (N=18)	
	No. of farmer	% of farmer	No. of farmer	% of farmer
15-19	2	11.11%	2	11.11%
20-25	3	16.67%	2	22.22%
26-30	6	33.33%	4	22.22%
31-35	3	16.66%	6	33.33%
36-40	3	16.66%	3	16.66%
>40	1	5.55%	1	5.55%

Table 9. Education of the farmers involved in fish farming in homestead ponds

Education level	Paba (N=18)		Tanore (N=18)	
	No. of farmer	% of farmer	No. of farmer	% of farmer
Illiterate	3	16.67	2	11.11
Primary	8	44.44	5	27.27
Class eight	5	27.27	6	33.33

SSC	3	16.67	3	16.67
HSC	2	11.11	1	05.57
Higher	0	00.00	1	05.57

Table 10. Training of the farmers involved in fish farming in homestead ponds

Training received on	Paba (N=18)		Tanore (N=18)	
	No. of farmer	% of farmer	No. of farmer	% of farmer
Aquaculture	0	00.00	3	16.67

Table 11. Household income of the farmers involved in fish farming in homestead ponds

Monthly income (BDT)	Paba (N=18)		Tanore (N=18)	
	No. of farmer	% of farmer	No. of farmer	% of farmer
<5,000	9	50%	3	16.67%
5,001-10,000	5	27.77%	7	38.88%
10,001-15,000	2	11.11%	5	27.77%
15,001-20,000	1	5.55%	2	11.11%
>20,000	1	5.55%	1	5.55%

Table 12. Profile of the homestead ponds

Aspects	Paba (N=18)			Tanore (N=18)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Area (ha)	00.08	00.12	00.18±0.001	00.08	00.26	00.11±0.01
Depth (m)	02.00	02.50	02.37±0.03	02.00	02.50	02.27±0.05
Age (Yrs)	20.00	40.00	33.05±1.52	10.00	40.00	29.44±2.62

Table 13. Production and economics (in terms of cost benefit ratio, CBR) of fish farming

Aspects	Paba (N=18)			Tanore (N=18)		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Fish production (kg/ha/yr)	2,699.00	4,000.00	3,164.72± 82.92	2,421.00	3,500.00	2,895.11± 75.32
BCR	0.18	0.31	0.25±0.01	0.12	0.28	0.21±0.01

Table 14. Major problems reported by the farmers under carp polyculture in homestead ponds

Sl. No.	Problems faced by the farmers	Paba (N=18)		Tanore (N=18)	
		No. of farmer	% of farmer	No. of farmer	% of farmer
1	Lack of appropriate technology	18	100.00	17	88.89
2	Insufficient water	15	83.33	16	83.33

3	Lack of quality fish seeds	14	77.78	14	72.22
4	Lack of low cost supplementary feed	13	72.22	15	77.78
5	Less fish production	12	66.67	10	55.57
6	Plankton bloom	09	50.00	13	66.67
7	No easy access to credit	08	44.44	09	50.00
8	Poaching and poisoning	07	38.89	06	33.33
9	Oxygen shortage	06	33.33	07	38.89
10	Mortality during high temperature	05	27.78	08	44.44
11	Gas forming	03	16.67	05	27.78
12	Disease occurrence	03	16.67	03	16.67

Table 15. Water quality under different treatments of carp fattening in ponds of Paba upazila, Rajshahi during study period (July-December, 2018)

Water quality	Treatments			F-value	P-value
	T_1	T_2	T_3		
Temperature (°C)	27.45±0.08a	27.79±0.09a	27.36±0.17a	3.20	0.11
DO (mg/l)	5.04±0.01c	5.66±0.05a	5.53±0.02b	99.77	0.00
pH	7.90±0.02a	7.95±0.01a	7.90±0.01a	3.71	0.09
Alkalinity (mg/l)	160.28±2.27a	165.83±1.27a	161.11±1.47a	3.00	0.13
Transparency (cm)	21.33±0.00c	30.55±0.11a	27.72±0.27b	749.72	0.00
NH3-N (mg/l)	0.04±0.01a	0.02±0.00b	0.03±0.01ab	9.00	0.02
TDS (mg/l)	502.14±1.25a	495.50±0.38c	499.47±2.28b	19.29	0.00
Plankton (cells/l)	432583.33± 21539.95a	357977.78± 8394.64b	267172.22± 23015.38c	19.35	0.00

Figures bearing common letter(s) in a rowdo not differ significantly (p>0.05)

Table 16. Fish growth under different treatments of carp fattening in ponds of Paba upazila, Rajshahi during study period (July-December, 2018)

Species	Treat ment	Initial weight (g)	Final weight (kg)	Weight gain (gd^{-1})	SGR (%, bwd^{-1})	Survival rate (%)
G. catla	T_1	410.00±0.58a	2.93±0.03a	16.31±0.31a	2.00±0.01a	92.00±1.00a
	T_2	405.00±2.89a	2.96±0.04a	16.48±0.42a	1.10±0.02a	90.67±0.58a
	T_3	408.33±1.33a	2.95±0.02a	16.42±0.21a	1.10±0.00a	91.67±0.57a
P value			0.824	0.829	0.579	0.154
F value			0.20	0.19	0.60	2.60
H. molitrix	T_1	408.00±1.15a	3.08±0.07a	17.13±0.40a	1.12±0.01b	93.67±0.33a
	T_2	406.33±4.98a	2.92±0.015a	16.24±0.08a	1.09±0.00a	92.00±0.57b
	T_3	411.67±2.40a	3.09±0.03a	17.16±0.17a	1.12±0.00a	93.33±0.33ab
P value			0.04	0.04	0.04	0.04
F value			4.09	4.10	5.40	4.20
L. rohita	T_1	397.33±3.71a	1.43±0.03c	7.96±0.18c	0.71±0.01c	90.00±0.57b
	T_2	402.00±3.79a	1.85±0.02a	10.28±0.16a	0.84±0.00a	92.33±0.33a
	T_3	406.33±4.00a	1.67±0.03b	9.27±0.18b	0.78±0.00b	90.00±0.57b
P value			0.000	0.000	0.000	0.027
F value			44.00	43.78	36.39	7.00

C. mrigala	T_1	334.00±4.93a	1.53±0.03b	8.53±0.17b	0.84±0.00b	92.00±0.54a
	T_2	333.00±3.51a	1.67±0.01a	9.31±0.04a	0.89±0.00a	92.33±0.33a
	T_3	335.00±1.15a	1.66±0.04a	9.26±0.24a	0.89±0.01a	92.00±0.54a
P value			0.040	0.04	0.034	0.840
F value			5.40	5.81	6.21	0.14
C. carpio	T_1	249.67±2.67	2.26±0.03b	12.55±0.17b	1.22±0.01b	94.00±0.57a
	T_2	247.33±1.45a	2.44±0.03a	13.55±0.17a	1.27±0.09a	93.66±0.33a
	T_3	249.67±2.67a	2.36±0.03ab	13.14±0.19ab	1.24±0.01ab	93.00±0.57a
P value			0.021	0.021	0.049	0.422
F value			7.90	7.42	5.18	1.00

Figures bearing common letter(s) in a column do not differ significantly (p>0.05)

Table 17. Fish yield (kg/ha/6 months) under different treatments of carp fattening in ponds of Pabaupazila, Rajshahi during study period (July-December, 2018)

Species	**Treatments**			**F-value**	**P-value**
	T_1	T_2	T_3		
G. catla	1019.79±21.12c	1355.93±26.99a	1193.50±12.42ab	63.77	0.00
H. molitrix	170.24±20.48c	900.60±3.56a	855.58±7.57b	47.74	0.00
L. rohita	881.33±26.15b	968.13±17.36a	947.50±18.96ab	4.58	0.04
C. mrigala	533.16±13.84b	599.53±7.58a	591.96±24.20a	4.74	0.04
C. carpio var. specularis	463.39±8.22b	503.32±5.42a	482.24±7.76ab	7.60	0.02
All species	3627.94±5.38c	4327.53±51.43a	4070.80±53.12b	68.36	0.00

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 18. Economics of carp fattening in pond (1 ha) of Paba upazila, Rajshahi for six months culture period (July-December, 2018)

Items	**Treatments**			**F-value**	**P-value**
	T_1	T_2	T_3		
Variable cost (BDT/ha)					
Seed	128221.04±892.02a	125585.41±732.47a	128188.33±686.83a	3.80	.08
Feed	456961.23±886.61a	478268.06±4295.13a	456924.6±11963.77a	2.80	0.13
Fixed cost (BDT/ha)					
Lease value	113500.00±0.00a	113500.00±0.00a	113500.00±0.00a	-	-
Water pump	10000.00±0.00a	10000.00±0.00a	10000.00±0.00a	-	-
Lime	11106.00±0.00a	11106.00±0.00a	11106.00±0.00a	-	-
Fertilizer	22779.00±0.00a	22779.00±0.00a	22779.00±0.00a	-	-
Labor	54000.00±0.00a	54000.00±0.00a	54000.00±0.00a	-	-
Harvest	25000.00±0.00a	25000.00±0.00a	25000.00±0.00a	-	-
Total cost (BDT/ha)	821567.28±550.59a	840238.47±5016.84a	821497.94±12308.46a	1.97	0.22
Total return (BDT/ha)	1012081.37±1835.11c	1174455.13±13890.27a	1113847.30±11977.21b	59.45	0.000
Net benefit (BDT/ha)	190514.09±1529.19c	334216.66±9275.56a	292349.36±12063.91b	70.05	0.000
BCR	0.23±0.00c	0.40±0.01a	0.35±0.02b	52.08	0.00

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 19. Water quality under different treatments of carp fattening in ponds of Tanore upazila, Rajshahi during study period (July-December, 2018)

Water quality	Treatments			F-value	P-value
	T_1	T_2	T_3		
Temperature (°C)	26.55±0.03a	26.35±0.09.26a	26.20±0.17a	0.91	0.45
DO (mg/l)	5.59±0.04c	6.17±0.06a	5.88±0.06b	26.37	0.00
pH	7.04±0.02a	7.15±0.03a	7.04±0.01a	2.40	0.17
Alkalinity (mg/l)	134.72±1.11a	137.77±2.64a	133.33±1.27a	1.57	0.28
Transparency (cm)	19.72±0.20c	23.16±0.42a	21.22±0.20b	34.68	0.00
NH3-N (mg/l)	0.04±0.00a	0.02±0.00b	0.02±0.00b	21.50	0.00
TDS (mg/l)	504.50±1.78a	499.25±1.39b	501.67±2.20b	9.42	0.01
Plankton (cells/l)	190441.67±19814.64a	70569.44±6244.98b	168455.55±10811.26a	22.27	0.00

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 20. Fish growth under different treatments of carp fattening in ponds of Tanore upazila, Rajshahi during study period (July-December, 2018)

Species	Treatment	Initial weight (g)	Final weight (kg)	Weight gain (gd^{-1})	SGR (%, bwd^{-1})	Survival rate (%)
G.catla	T_1	414.67±1.45a	2.94±0.03a	16.33±0.30a	1.09±0.01a	91.67±0.33a
	T_2	412.67±0.88a	3.03±0.04a	16.76±0.42a	1.10±0.01a	90.66±0.33a
	T_3	412±2.65a	2.93±0.05a	16.28±0.25a	1.09±0.01a	92.33±0.3a
P value			0.31	0.31	0.36	0.03
F value			1.41	1.41	1.23	6.33
H. molitrix	T_1	409.67±2.40a	2.95±0.05a	16.39±0.28a	1.09±0.01a	93.33±0.33a
	T_2	412.67±2.60a	2.94±0.02a	16.35±0.13a	1.09±0.01a	91.33±0.33b
	T_3	409.33±1.86a	2.99±0.01a	16.63±0.04a	1.10±0.00a	93±0.58a
P value			0.53	0.53	0.46	0.04
F value			0.72	0.72	0.89	6.20
L. rohita	T_1	403±2.89a	1.45±0.23c	8.05±0.16c	0.71±0.02c	90.00±0.58b
	T_2	412±2.08a	1.92±0.04a	10.65±0.25a	0.85±0.01a	92.33±0.33a
	T_3	403±4.51a	1.58±0.02b	8.80±0.09b	0.76±0.01b	89.00±0.58b
P value			0.000	0.000	0.000	0.01
F value			56.73	57.35	30.70	11.29
C. mrigala	T_1	344.33±4.06a	1.48±0.02b	8.24±0.09b	0.80±0.00b	92.67±0.33ab
	T_2	341±3.06a	1.75±0.10a	9.72±0.58a	0.91±0.03a	93.67±0.33a
	T_3	336.33±4.06a	1.58±0.02ab	8.80±0.09b	0.86±0.01ab	92.33±0.33b
P value			0.06	0.06	0.04	0.07
F value			4.78	4.77	6.06	4.33
C. carpio	T_1	250±4.39	1.48±0.04b	8.24±0.21b	0.99±0.02b	94.00±0.58a
	T_2	247.33±2.19a	1.67±0.03a	9.26±0.18a	1.06±0.01a	95.00±0.58a
	T_3	249±2.08a	1.62±0.04ab	8.98±0.25a	1.04±0.01ab	93.33±0.03a
P value			0.04	0.04	0.04	0.15
F value			6.02	6.08	5.57	2.71

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 21. Fish yield (kg/ha/6 months) under different treatments of carp fattening in ponds of Tanore upazila, Rajshahi during study period (July-December, 2018)

Species	Treatments			F-value	P-value
	T_1	T_2	T_3		
G. catla	1014.82±8.62c	1378.09±17.87b	1189.78±24.52a	99.56	0.00
H. molitrix	692.99±15.88c	897.59±10.64b	821.25±7.85a	75.10	0.00
L. rohita	885.71±20.68b	1006.54±35.306a	869.24±4.09b	9.97	0.012
C. mrigala	505.03±8.63b	640.38±46.898a	555.35±10.03ab	5.91	0.038
C. carpio var. specularis	282.95±11.49b	329.94±5.56a	311.36±8.87ab	6.96	0.027
All species	3381.52±32.62c	4252.54±79.37a	3746.99±33.91b	67.41	0.00

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 22. Economics of carp fattening in pond (1 ha) of Tanore upazila, Rajshahi for six months culture period (July-December, 2018)

Items	Treatments				
Var. cost (BDT/ha)	T_1	T_2	T_3	F value	P value
Seed	130336.15±387.88a	128177.36±74.29b	128035.99±421.54b	11.71	.00
Feed	484766.66±2304.29b	468283.13±6474.20a	446076.60±5987.38b	5.30	.04
Fixed cost (BDT/ha)					
Lease value	101150.00±0.00 a	101150.00±0.00 a	101150.00±0.00 a	-	-
Water pump	10000.00±0.00 a	10000.00±0.00 a	10000.00±0.00 a	-	-
Lime	13320.00±0.00 a	13320.00±0.00 a	13320.00±0.00 a	-	-
Fertilizer	22875.00±0.00 a	22875.00±0.00 a	22875.00±0.00 a	-	-
Labour	54000.00±0.00 a	54000.00±0.00 a	54000.00±0.00 a	-	-
Harvest	25000.00±0.00 a	25000.00±0.00 a	25000.00±0.00 a	-	-
Total cost	805605.22±1888.19ab	822805.50±6404.43a	800457.59±6246.62b	4.91	0.05
Total return	973955.08±7367.12ab	1172753.13±18001.88a	1052451.73±8893.97b	65.75	0.000
Net profit	168349.86±5789.13c	349947.63±14691.16a	251994.14±10665.91b	68.25	0.000
BCR	0.21±0.01c	0.42±0.02a	0.31±0.01b	67.46	0.00

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 23. Concentration of pathogenic bacteria (MPN/g) in carp fattening ponds of Paba upazila, Rajshahi during study period (July-December, 2018)

Treatment / Bacteria	T_1	T_2	T_3	F value	P value
Soil					
Total coliform	$609.56±111.41^a$	$453.44±52.74^a$	$218.67±17.51^b$	16.08	0.00
Total faecal	$344.44±122.39^a$	$176.89±24.06^a$	$172.39±29.09^a$	1.76	0.25
Water					
Total coliform	$397.48±142.26^a$	$182.37±37.05^a$	$117.01±22.70^a$	2.92	0.13
Total faecal	$332.16±148.04^a$	$101.57±15.70^a$	$78.37±9.79^a$	2.65	0.15

Figures in a row bearing common letters as superscript do not differ significantly (p>0.05).

Table 24. Concentration of pathogenic bacteria (MPN/g) in carp fattening ponds of Tanore upazila, Rajshahi during study period (July-December, 2018)

Treatment / Bacteria	T_1	T_2	T_3	F value	P value
Soil					
Total coliform	539.94±52.01[a]	310.94±90.76[b]	159.50±43.90[b]	8.55	0.02
Total faecal	487.89±72.41[a]	302.78±92.60[ab]	114.56±17.88[b]	7.39	0.02
Water					
Total coliform	322.39±106.63[a]	222.61±89.42[a]	122.61±89.42[a]	1.52	0.29
Total faecal	202.78±5.82[a]	216.94±91.08[a]	82.95±21.66[a]	1.85	0.24

Figures in a row bearing common letters as superscript do not differ significantly (p>0.05).

Table 25. Heavy metal concentration in water and fish feed under carp fattening system of the study sites

Heavy metal	Source	
	Pond water (ppm)	Fish feed (ppm)
Lead (Pb)	0.003±0.00	0.007±0.00
Cadmium (Cd)	0.025±0.00	0.016±0.00

Table 26. Water quality under different treatments of SIS-carp farming in ponds under Paba upazila, Rajshahi during study period (July-December, 2018)

Water quality	Treatments			F-value	P-value
	T_1	T_2	T_3		
Temperature (°C)	27.08±0.13a	27.46±0.13a	27.08±0.14a	2.74	0.14
DO (mg/l)	5.06±0.06a	5.20±0.01a	5.14±0.05a	2.62	0.15
pH	7.17±0.05a	7.14±0.03a	7.17±0.05a	0.14	0.87
Alkalinity (mg/l)	113.44±3.39a	115.22±5.70a	116.11±2.10a	0.11	0.89
Transparency (cm)	30.72±0.56a	30.61±0.29a	30.06±0.11a	0.94	0.44
NH3-N (mg/l)	0.04±0.00a	0.02±0.00b	0.03±0.00b	4.56	0.06
TDS (mg/l)	602.14±1.25a	595.50±0.38c	599.47±2.29b	19.29	0.00

Figures bearing common letter(s) in a rowdo not differ significantly (P >0.05)

Table 27. Fish growth under different treatments of SIS-carp farming in ponds under Paba upazila, Rajshahi during study period (July-December, 2018)

Species	Treatment	Initial weight (g)	Final weight (g)	Weight gain (g/6months)	SGR (%, bwd^{-1})	Survival rate (%)
H.fossilis/ C.batrachus /M.cavacius	T_1	0.70±0.006a	83.83±0.34b	83.14±0.35b	2.66±0.01b	89.75±0.07a
	T_2	0.72±0.018a	120.68±0.25c	110.41±0.21a	2.80±0.01a	89.32±0.94a
	T_3	0.68±0.009a	11.13±0.21a	20.00±0.25c	1.90±0.01c	85.90±1.14b
P value		-	0.00	0.00	0.00	0.04
F value		-	28.19	28.28	39.38	6.02
G. catla	T_1	169.00±2.08a	893.78±0.33a	724.78±0.34b	0..93±0.00b	83.40±0.84a
	T_2	169.00±2.08a	892.11±1.73a	728.44±1.00a	0.94±0.00a	83.67±1.35a
	T_3	167.00±3.06a	891.61±0.28a	724.61±0.29b	0.93±0.00b	83.94±1.48a
P value		-	0.11	0.00	0.00	0.96
F value		-	3.24	11.75	13.00	0.05

H. molitrix	T_1	232.33±3.93a	1265.70±3.51b	1033.37±3.34b	0.94±0.00a	84.84±0.51a
	T_2	232.67±3.93a	1275.13±2.03a	1042.46±2.21a	0.95±0.00a	84.96±0.55a
	T_3	234.00±4.16a	1276.68±3.27a	1042.68±1.93a	0.94±0.00a	84.96±0.55a
P value		-	0.47	0.07	0.08	0.99
F value		-	5.29	4.29	4.00	0.02
L. rohita	T_1	142.33±1.45a	752.13±0.15b	609.81±0.16b	0.92±0.00b	81.78±0.62a
	T_2	139.33±2.96a	753.62±0.31a	614.29±0.32a	0.94±0.00a	81.91±1.05a
	T_3	137.33±2.96a	751.06±0.45b	613.74±0.46a	0.94±0.00a	81.64±0.71a
P value		-	0.00	0.00	0.00	0.97
F value		-	14.74	53.50	25.00	0.03

Figures bearing common letter(s) in a column do not differ significantly (p>0.05)

Table 28. Fish yield (kg/ha/6 months) under different treatments of SIS-carp farming in ponds under Paba upazila, Rajshahi during study period (July-December, 2018)

Species	**Treatments**			**F-value**	**P-value**
	T_1	T_2	T_3		
H.fossilis/ C.batrachus/ M. cavasius	2734.52±43.72b	3651.29±33.65a	633.40±16.38c	3523.09	0.00
H. molitrix	499.91±4.46a	505.31±4.65a	505.30±4.15a	0.49	0.63
G. catla	142.37±1.91a	143.93±2.87a	143.60±3.21a	0.09	0.91
L. rohita	116.77±1.14a	118.06±1.90a	117.54±1.28a	0.19	0.83
All species	3493.59±30.44b	4418.61±32.29a	1399.85±8.81c	3504.25	0.00

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 29. Economics of SIS-carp farming in pond (1 ha) under Paba upazila, Rajshahi for six months culture period (July-December, 2018)

Items	**Treatments**			**F-value**	**P-value**
	T_1	T_2	T_3		
Variable cost (BDT/ha)					
Seed	221185.00±0.00a	221185.00±0.00a	219332.00±0.00a	-	-
Feed	212141.65±515.71b	253781.28±734.53a	46079.81±644.32c	29677.34	0.00
Fixed cost (BDT/ha)					
Lime	9129±0.00a	9129±0.00a	9129±0.00a	-	-
Fertilizer	22575.00±60.65a	22570.33±49.10a	22627.00±91.31a	0.21	0.82
Labour	22390.00±598.08a	22803.33.±1024.21a	22350.00±606.22a	0.11	0.90
Harvest	18500.00±0.00a	18500.00±0.00a	18500.00±0.00a	-	-
Total cost (BDT/ha)	505920.65±870.69b	547968.95±359.98a	338018.31±309.91c	376331.15	0.00
Total return (BDT/ha)	1166498.61±10200.55b	1405571.95±11439.44a	467272.83±7627.75c	2434.48	0.00
Net benefit (BDT/ha)	600577.96±10211.43b	857603.00±11210.86a	129254.52±7461.15c	1490.79	0.00
BCR	1.31±0.02b	1.57±0.02a	0.38±0.02c	899.96	0.00

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 30. Water quality under different treatments of SIS-carp farming in ponds under Tanore upazila, Rajshahi during study period (July-December, 2018)

Water quality	Treatments			F-value	P-value
	T_1	T_2	T_3		
Temperature (°C)	27.40±0.18a	27.63±0.18a	27.36±0.23a	0.62	0.56
DO (mg/l)	4.90±0.08a	4.93±0.07a	4.89±0.06a	0.90	0.90
pH	7.02±0.07a	7.00±0.08a	7.08±0.08a	0.28	0.76
Alkalinity (mg/l)	91.66±1.35a	92.72±1.05a	91.77±2.15a	0.13	0.87
Transparency (cm)	22.16±0.14a	22.38±0.26a	22.18±0.36a	0.18	0.83
NH3-N (mg/l)	0.02±0.00a	0.02±0.00a	0.02±0.00a	1.19	0.36
TDS (mg/l)	304.53±6.39a	307.42±6.15a	355.16±13.76a	0.10	0.90

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 31. Fish growth under different treatments of SIS-carp farming in ponds under Tanore upazila, Rajshahi during study period (July-December, 2018)

Species	Treatment	Initial weight (g)	Final weight (g)	Weight gain (g/6 months)	SGR (%, bwd^{-1})	Survival rate (%)
H.fossilis/ C. batrachus/ M.cavacius	T_1	0.70±0.009a	89.57±0.28b	88.87±0.28b	2.69±0.00b	89.49±0.88a
	T_2	0.71±0.009a	119.60±0.30a	118.88±0.31a	2.83±0.01a	91.57±0.76a
	T_3	0.69±0.007a	22.53±0.23c	21.85±0.24c	1.94±0.00c	87.90±1.34a
P value		-	0.00	0.00	0.00	0.11
F value		-	32.64	31.92	29.68	3.183
G.catla	T_1	155.00±2.89a	836.19±2.00a	681.19±2.00a	0..93±0.00a	82.19±0.46a
	T_2	155.00±4.04a	836.09±3.78a	681.09±3.78a	0.93±0.00a	82.04±0.58a
	T_3	159.33±3.48a	832.60±1.75a	673.27±1.75a	0.92±0.00b	81.77±0.61a
P value		-	0.58	0.13	0.00	0.87
F value		-	0.58	2.89	12.50	0.13
H. molitrix	T_1	216.67±8.82a	1196.21±1.39a	979.54±1.39b	0.95±0.00a	82.55±1.29a
	T_2	207.33±6.23a	1192.38±0.90a	985.05±0.90b	0.97±0.00a	83.77±0.48a
	T_3	215.00±2.89a	1197.48±0.73b	982.48±0.73ab	0.95±0.00a	83.77±0.58a
P value		-	0.03	0.02	0.00	0.54
F value		-	6.39	6.92	0.00	0.66
L. rohita	T_1	137.67±1.45a	715.75±0.33b	578.08±0.33a	0.92±0.00b	80.42±0.75a
	T_2	135.67±2.33a	716.32±0.28a	580.65±0.28a	0.92±0.00b	80.98±1.45a
	T_3	133.00±2.52a	715.73±2.59b	582.73±2.59a	0.93±0.00a	80.71±1.08a
P value		-	0.95	0.17	0.00	0.94
F value		-	0.04	2.35	25.00	0.06

Figures bearing common letter(s) in a column do not differ significantly (p>0.05)

Table 32. Fish yield (kg/ha/6 months) under different treatments of SIS-carp farming in ponds under Tanore upazila, Rajshahi during study period (July-December, 2018)

Species	Treatments			F- value	P-value
	T_1	T_2	T_3		
H.fossilis/ C. batrachus/ M. cavasius	2944.24±22.93b	4031.44±42.86a	709.02±18.30c	3190.47	0.00
H. molitrix	467.41±1.80a	470.25±2.96a	468.24±4.44a	0.20	0.82
G.catla	131.45±0.73a	131.15±0.87a	128.83±1.50a	1.73	0.25
L. rohita	108.19±1.30a	109.75±2.56a	109.80±1.50a	0.24	0.79
All species	3651.30±22.91b	4742.60±75.88a	1415.90±11.28c	3354.53	0.00

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 33. Economics of SIS-carp farming in pond (1 ha) under Tanore upazila, Rajshahi for six months culture period (July-December, 2018)

Items	Treatments			F-value	P-value
	T_1	T_2	T_3		
Variable cost (BDT/ha)					
Seed	221185.00±0.00a	221185.00±0.00a	219332.00±0.00a	-	-
Feed	309141.65±515.71b	448181.28±734.53a	70919.81±644.32c	89464.99	0.00
Fixed cost (BDT/ha)					
Lime		12000.00±0.00a	12000.00±0.00a	-	-
Fertilizer	22575±60.66a	22570.33±49.10a	22627.00±91.31a	0.21	0.82
Labour	22390.00±598.08a	22683.33.±1024.21a	22350.00±606.22a	0.11	0.90
Harvest	18500.00±0.00a	18500.00±0.00a	18500.00±0.00a	-	-
Total cost (BDT/ha)	605791.65±770.70b	745239.95±359.98a	365729.31±309.91c	112379.35	0.00
Total return (BDT/ha)	1252993.77±8733.01 b	1610951.14±15650.85 a	498466.95±8732.60 c	2434.21	0.00
Net benefit (BDT/ha)	647202.12±9027.59b	65711.19±15583.53a	132737.63±8486.74 c	1071.81	0.00
BCR	1.07±0.02b	1.16±0.02a	0.37±0.03c	476.15	0.00

Figures bearing common letter(s) in a rowdo not differ significantly (p>0.05)

11.2. Survey findings on carp polyculture in homestead ponds by component 2 (PSTU)

The survey findings in terms of the fish farmers profile, pond profile, production of carp polyculture and problems faced by the farmers.

2.a. *Fish farmer's profile*

A total of 36 farmers were selected in the study areas. Majority of the farmers were found between the age of 26 and 35 years. Majority of the farmers were found with primary level (60

%) education. Almost 68% farmers reported that they received training on aquaculture (Fig 6). Almost 70% farmers were found with the monthly household income as BDT 5,001.00 to 10,000.00.

2.b. Pond profile

The profile of the ponds in terms of area, pond ownership and pond type is shown in Figs. 3 – 6.

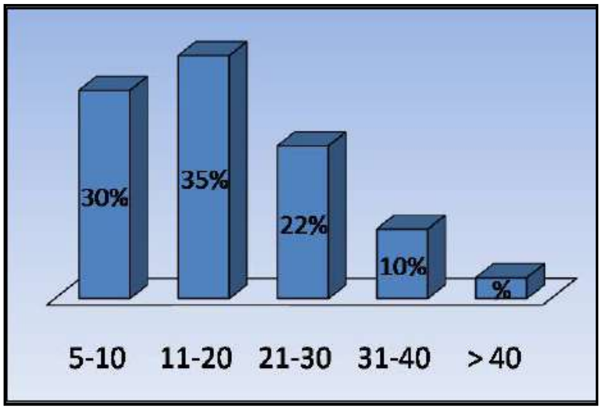


Fig. 3. Pond area (decimal)

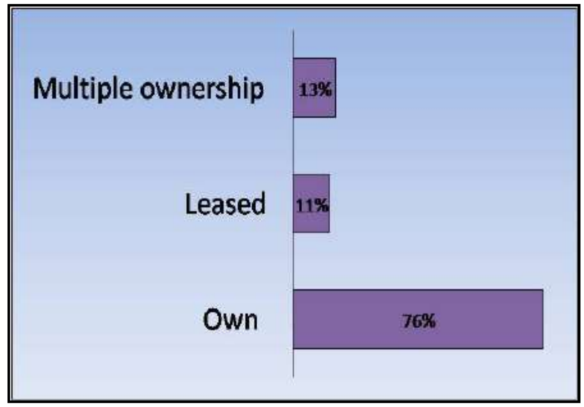


Fig. 4. Pond ownership

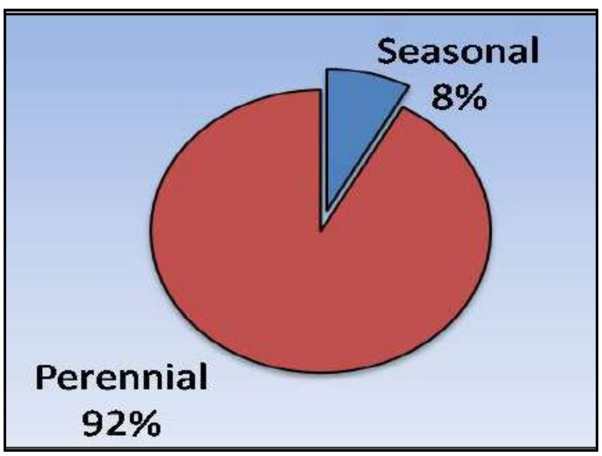


Fig. 5. Pond type

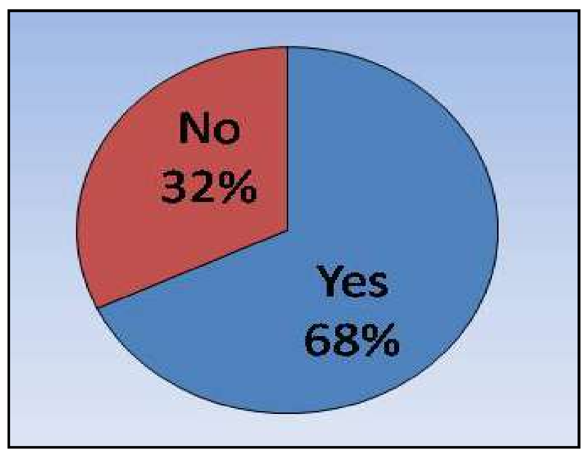


Fig. 6. Training received

2.c. Production of fish farming in homestead ponds

Most of the fish farmers were practiced in a traditional way. So, the production of fish was low. The mean fish production (kg/ha/yr) in the study areas varied from 1,693.11±105.43.

2.d. Problems faced by the farmers in homestead ponds

Problems were mostly related to lack of appropriate fish farming technology for homestead ponds, lack of quality fish seed, oxygen shortage, mortality during winter season, no easy access to credit for farming and occurrence of disease.

11.2.2. Determination of suitable species combination for carp fattening in ponds under coastal area

2.a. Water quality parameters

The mean value of water quality parameters viz., water temperature, dissolved oxygen, pH, TDS, CO_2, alkalinity, nitrate, ammonia and plankton abundance were measured during the study period are shown in Table 2.1.

Table 34. Water quality parameters for carp ponds during the study period (mean ± SD)

Parameters	Treatment		
	$SC\text{-}S_{30}C_{40}B_{30}$	$SC\text{-}S_{40}C_{30}B_{30}$	$SC\text{-}S_{35}C_{35}B_{30}$
Temperature (^{0}C)	29.65±2.05	29.87±3.86	29.42±1.04
DO (mg/l)	5.36±0.54	5.31±0.63	5.45±0.94
pH	7.822±0.32	8.156±0.52	8.22±0.28
TDS (mg/l)	255±75.85	225.77±150.70	233.88±90.37
CO_2 (mg/l)	5.11±3.10	2.22±3.70	3.44±4.21
Alkalinity (mg/l)	203.88±86.12	258.55±126.65	247.22±174.30
Nitrate (mg/l)	0.36±0.24	0.28±0.15	0.50±0.41
Ammonia (mg/l)	0.06±0.076	0.04±0.05	0.01±0.02
Plankton abundance (× 10^3 cells/l)	4.44+0.73	3.94+0.39	3.88+0.54

Water quality parameters were not significantly different among the treatments. All water quality parameters were found within the suitable range for carp fish culture. The mean dissolved oxygen (mg/l) contents were 5.36 mg/l, 5,31 mg/l, 5.45 mg/l in $SC\text{-}S_{30}C_{40}B_{30}$, $SC\text{-}S_{40}C_{30}B_{30}$ and $SC\text{-}S_{35}C_{35}B_{30}$, respectively (Table 34). For optimal fish growth, DO levels should be above 5 mg/l for warm water fish species (Boyd, 1982). The mean values of pH were 7.82, 8.16 and 8.22 in $SC\text{-}S_{30}C_{40}B_{30}$, $SC\text{-}S_{40}C_{30}B_{30}$ and $SC\text{-}S_{35}C_{35}B_{30}$, respectively, which indicate good productive conditions. The present findings were within acceptable range (6.5 to 8.5) required for fish culture (DoF, 1996). The mean alkalinity (mg/l) were found 203.88 mg/l, 258.55 mg/l, 247.22mg/l, 199.33 mg/l in $SC\text{-}S_{30}C_{40}B_{30}$, $SC\text{-}S_{40}C_{30}B_{30}$ and $SC\text{-}S_{35}C_{35}B_{30}$, respectively, which indicated also good productive condition. According to Alikunhi (1957) total alkalinity more than 100 ppm should be present in more productive water bodies. During the experimental period ammonia (mg/l) was ranged at 0.06mg/l, 0.04mg/l, 0.01mg/l in $SC\text{-}S_{30}C_{40}B_{30}$, $SC\text{-}S_{40}C_{30}B_{30}$ and $SC\text{-}S_{35}C_{35}B_{30}$, respectively. Bhatnagar and Singh (2010) recommended the level of ammonia (<0.2 mg/l) suitable for pond fishery that indicated desirable range of ammonia were recorded in the study period.

11.2.3. Production performance of fish

Production performance of carp fishes in term of weight (g) gain under different treatments for a period of 270 days is presented in the Table 35. For the evaluation of production performance of carp fishes in three treatments in terms of final weight (g) gain, specific growth rate (SGR, percent per day), survival rate and production (kg/ha) were calculated.

Table 35. Growth performances of carps observed in different treatment

Parameters	Treatment		
	SC-$S_{30}C_{40}B_{30}$	SC-$S_{40}C_{30}B_{30}$	SC-$S_{35}C_{35}B_{30}$
Initial wt (g)	145±000	145±000	145±000
Final wt (g)	1580.00±108.17[b]	1593.33±35.47[b]	1780.00±75.49[a]
SGR (%/day)	0.88±0.03[b]	0.89±0.01[b]	0.93±0.01[a]
Survival rate (%)	93.36±1.61	92.93±1.65	92.81±3.08
Production (kg/ha/270 d)	3640.92±187.82[b]	3656.47±16.84[b]	4078.52±148.32[a]

The SGR of carp in different treatment ranged between 0.88 and 0.93. The significantly highest SGR values (0.93) for carp was found in SC-$S_{35}C_{35}B_{30}$ whereas lowest SGR values (0.88) was found in SC-$S_{30}C_{40}B_{30}$. Production of carp in treatments SC-$S_{30}C_{40}B_{30}$, SC-$S_{40}C_{30}B_{30}$ and SC-$S_{35}C_{35}B_{30}$ were found 3640.92±187.82 kg/ha, 3656.47±16.84 kg/ha and 4078.52±148.32 kg/ha, respectively with higher production recorded in SC-$S_{35}C_{35}B_{30}$ which might be associated with higher SGR of carp obtained in this treatment.

11.2.4. The economic analysis

The economic analysis of the experiment is shown in Table 36.

Table 36. BCR calculations for carps

	SC-$S_{30}C_{40}B_{30}$	**SC-$S_{40}C_{30}B_{30}$**	**SC-$S_{35}C_{35}B_{30}$**
Total variable costs (Taka)	378453	394942	372502
Total income (Taka)	582547	585035	652563
Net benefit (return)	204094	190093	280061
Benefit Cost Ratio (BCR)	1.54	1.48	1.75

Total variable costs were observed Tk. 378453/ha, 394942/ha and 372502/ha in treatments SC-$S_{30}C_{40}B_{30}$, SC-$S_{40}C_{30}B_{30}$ and SC-$S_{35}C_{35}B_{30}$, respectively (Table 36). The total income was calculated Tk. 582547/ha, 585035/ha and 652563/ha in treatments SC-$S_{30}C_{40}B_{30}$, SC-$S_{40}C_{30}B_{30}$ and SC-$S_{35}C_{35}B_{30}$, respectively. The highest total income was observed in SC-$S_{35}C_{35}B_{30}$. Among three treatments, SC-$S_{35}C_{35}B_{30}$ was made Tk. 280061/ha net benefit then SC-$S_{30}C_{40}B_{30}$ was earned Tk. 204094/ha and SC-$S_{40}C_{30}B_{30}$ earned Tk. 190093/ha. BCR was obtained 1.54, 1.48 and 1.75 in SC-$S_{30}C_{40}B_{30}$, SC-$S_{40}C_{30}B_{30}$ and SC-$S_{35}C_{35}B_{30}$, respectively. BCR was higher in SC-$S_{35}C_{35}B_{30}$ because of the highest yield was obtained in SC-$S_{35}C_{35}B_{30}$ than the other treatments.

11.2.5. Species suitability for farming of SIS fishes in homestead ponds under coastal area

3.a. Water quality parameters

Water quality parameters of a large number of samples were analyzed in this experiment to observe any appreciable changes that might have occurred in response to different treatments. The overall mean values of each water quality parameter were varied slightly across the treatments (Table37). The mean values of water temperature, nitrite, alkalinity, pH, DO, ammonia, CO_2 and TDS were ranged from 28.87 ± 0.83 to29.88 ± 0.67 ^oC, 0.32 ± 0.18 to 0.42 ± 0.33 mg/l, 211.11 ± 81.76 to 367.77 ± 151.39 mg/l, 7.53 ±0.43 to 7.70 ± 0.63, and 5.24 ± 0.53 to 5.39 ± 0.64 mg/l, 0.02 ± 0.07 to 0.03 ± 0.07 mg/l, 1.00 ± 2.00 to 6.72 ± 5.76 mg/l, and 209.05 ± 113.56 to 289.22 ± 144.91 mg/l, respectively among the treatments. There was no significant difference ($p < 0.05$) observed in all water quality parameters among different treatments except CO_2 concentration. Significantly ($p < 0.05$) highest and lowest CO_2 concentration was found in SP-magur (6.72 ± 5.76 mg/l) and SP-shing (1.00 ± 2.00 mg/l), respectively.

Table 37. Water quality parameters for SIS ponds during the study period

Parameters	Treatment		
	SP-Magur	SP-Shing	SP-Gulsha
Temperature (^0C)	28.87±0.83	29.88±0.67	29.33±0.54
Nitrate (mg/l)	0.41±0.27	0.32±0.18	0.42±0.33
Alkalinity (mg/l)	211.11±81.76	367.77±151.39	268.88±208.11
pH	7.53±0.43	7.70±0.63	7.62±0.63
DO (mg/l)	5.39±0.64	5.24±0.53	5.31±0.60
Ammonia (mg/l)	0.02±0.066	0.03±0.07	0.02±0.03
CO_2 (mg/l)	6.72±5.76[a]	1.00±2.00[b]	3.38±2.93[ab]
TDS (mg/l)	289.22±144.91	240.55±127.31	209.05±113.56
Plankton abundance (× 10^3 cells/l)	5.83+0.74	5.99+0.47	6.29+0.23

The physical, chemical, and biological parameters measured in each treatment of this experiment over the entire period of research were found to be more or less similar to the results of several previous studies (Dewan, 1973; Ali *et al*., 1982; Wahab *et al*., 1996).

3.b. Fish growth performances

Growth performance of *C. batrachus*, *H. fossilis*, and *M. cavasius* were observed during culture period (nine months) in homestead ponds of coastal area. Significant variation (p <0.05) was found among the treatments in terms of specific growth rate (SGR), and highest and lowest SGR (%/day) was found in SP-Magur (1.84 ± 0.04) and SP-Gulsha (1.37 ± 0.06), respectively. Among three SIS species, fish production was maximum in SP-magur (3289.52 ± 372.44 kg/ha/270 days) which varied significantly (p <0.05) from SP-shing (1699.44 ± 274.74kg/ha/270 days) and SP-Gulsha (865.70 ± 123.34kg/ha/270 days).

Table 38. Growth performances of SISobserved in different treatments

Parameters	**Treatment**		
	SP-Magur	SP-Shing	SP-Gulsha
Initial weight (g)	0.70±0.00	0.76±0.00	0.71±0.00
Final weight (g)	102.00±12.00[a]	56.67±10.41[b]	29.00±5.29[c]
SGR (%/day)	1.84±0.04[a]	1.59±0.07[b]	1.37±0.06[c]
Survival rate (%)	87.14±3.49	81.27±5.06	80.17±3.79
Production (kg/ha/270 d)	3289.52±372.44[a]	1699.44±274.74[b]	865.70±123.34[c]

The mean weight gain was higher in SP-magur that may be due to the higher growth rate of *Clarias batrachus* than the other two species. Availability of space and reduced competition and stress may have contributed to the result obtained in this present study. This result is in agreement with Narejo*et al*. (2005) who reported better growth at lower stocking density. The survival rate was higher in SP-Magur and followed by SP-shing and SP-Gulsha that may be due to higher adaptability of walking catfish (*C. batrachus*). As the weight gain and survival rate was higher in SP-magur, the total production was also higher in SP-magur.

3.c. Economic analysis

Total cost and total income were found highest in treatment SP-magur followed by SP-shing and SP-Gulsha. Both the total variable cost and total income was highest and lowest in SP-magur (618803.00/- and 1315600.00/- BDT) and SP-Gulsha (421212.00/- and 432850.00/- BDT), respectively. Moreover, net benefit or return was maximum in SP-Magur (696797.00/- BDT) and minimum in SP-Gulsha (11638.00/- BDT).

Table 39. Total variable cost (Taka), total income (Taka), net benefit (Taka) and benefit-cost ratio (BCR) calculations of three SIS species

Parameters	**SP-Magur**	**SP-Shing**	**SP-Gulsha**
Total variable costs (Taka)	618803.00/-	520302.00/-	421212.00/-
Total income (Taka)	1315600.00/-	764550.00/-	432850.00/-
Net benefit (return) (Taka)	696797.00/-	244248.00/-	11638.00/-
Benefit-Cost Ratio (BCR)	2.13	1.47	1.03

From the experiment it was found that the highest net profit was BDT 696797.00 per hectare in SP-Magur. The similar result was found by Alim et. al.(2005) who stated that the highest benefit was found at lower stocking density in 98 days.

11.3. Carp fattening experiment by in ponds by component 1 (RU) in 2019

Major findings (in terms of water quality, fish growth and yield, economics and GAP aspects) of the carp fattening experiments conducted in Paba and Tanore upazilas are shown in Table 40 – 50.

11.3.1 Carp fattening in ponds of Paba upazila, Rajshahi

1.a. Water quality

Variations in the mean values of water quality parameters are shown in Table 40. No significant difference was found among the treatments for the mean water quality parameters except dissolved oxygen. Comparatively higher value of dissolved oxygen and lower value of ammonia-nitrogen was found with treatment T_1 which received lowest stocking density. Present findings clearly indicates that lower stocking density along with the presence of surface feeder specially the silver carp (with appropriate number in polyculture ponds) can play a significant role for improvement in water quality and it was reflected well while most of the parameters were found within suitable range for fish farming specially with treatment T_1 .

1.b. Fish growth

Variations among the treatments in growth performances (in terms of initial weight, final weight, daily weight gain, specific growth rate and survival rate) of fishes during culture period are shown in Table 41. Growth parameters of all the fish species varied significantly ($P < 0.05$)with the treatments. Significantly higher values of mean final weight, daily weight gain and survival rate of fishes were found with lowest stocking density treatment (T_1). Findings indicated that lowest stocking density favored the growth of fishes in treatment T1.

1.c. Fish yield

Variations in the fish yield under the treatments are shown in Table 42. All the treatments varied significantly ($p<0.05$) for the yield of different fish species except carpio. Treatment T_3 varied more significantly than other treatments during study. Fish yield with treatment T_3 (receiving highest stocking density) was 11.11% higher than treatment T_1 and 5.56% higher than treatment $T_{2.}$

1.d. Economics of carp fattening

Variations in the mean values of cost, net benefit and BCR are shown in Table 43. Significant difference ($p<0.05$) was found among the treatments for the mean values of total cost, total cost) with the treatments. Apart from the feed, two other important factors like lease value (14.52-14.95%) and water addition (1.17-1.81% of the total cost) for the ponds increased the cost of fish production through carp fattening in drought prone area. Net benefit with treatment T_1 was 38.96% higher than treatment T_2 and 51.54% higher than treatment $T_{3.}$

11.3.2. Carp fattening in ponds of Tanore upazila, Rajshahi

2.a. Water quality

Variations in the mean values of water quality parameters are shown in Table 44. No significant difference was found among the treatments for the mean water quality parameters except dissolved oxygen. Comparatively higher value of dissolved oxygen and lower value of ammonia-nitrogen was found with treatment T_1 which received lowest stocking density. Comparatively higher clay turbidity in pond is the common character of the fish ponds under barind area of Bangladesh and it is reflected well in this study while finding comparatively lower water transparency with the treatments. However, most of the parameters were found within more or less suitable range for fish farming.

2.b. Fish growth

Variations among the treatments in growth performances (in terms of initial weight, final weight, daily weight gain, specific growth rate and survival rate) of fishes during culture period are shown in Table 45. Growth parameters of all the fish species varied significantly ($P < 0.05$)with the treatments. Significantly higher values of mean final weight, daily weight gain and survival rate of fishes were found with lowest stocking density treatment (T_1). Findings indicated that lowest stocking density favored the growth of fishes in treatment T_1.

2.c. Fish yield

Variations in the fish yield under the treatments are shown in Table 46. All the treatments varied significantly ($p<0.05$) for the yield of different fish species except Catla and Mrigal. Treatment T_3 varied more significantly ($P < 0.05$) than other treatments during study. Fish yield with treatment T_3 was 11.95% higher than treatment T_1 and 6.86% higher than treatment$T_{2.}$

2.d. Economics of carp fattening

Variations in the mean values of cost, net benefit and BCR are shown in Table 47. Significant difference ($p<0.05$) was found among the treatments for the mean values of total cost, total return, net benefit and BCR. Feed was the major cost involving area (57.36-59.61% of the total cost) with the treatments. Apart from the feed, two other important factors like lease value (12.30-12.73%) and water addition (1.21-1.25% of the total cost) for the ponds increased the cost of fish production through carp fattening in drought prone area. Net benefit with treatment T_1 was 40.62% higher than treatment T_2 and 50.77% higher than treatment $T_{3.}$

11.3.3. GAP aspects of carp fattening ponds

GAP aspects in terms of pathogenic bacteria and heavy metal concentration are shown in Table 48-50. Some of the countries follow to keep an acceptable level of total coliform bacteria for aquaculture in freshwater as 100-5,000 MPN. Findings of the study indicated that the concentration of total coliform bacteria in pond water of both the sites was within the more or less acceptable range. Concentration of cadmium (0.014-0.023 ppm) was found higher than lead (0.003-0.006 ppm) during study (Table 50). The acute toxic concentrations of lead in different types of water are in the range of 10 to 100 mg/l for cyprinids. The maximum admissible lead concentration in water is 0.07 mg/l for cyprinids. For cyprinids, the maximum admissible cadmium concentration in water is 0.001 mg per litre and the acute lethal concentration of cadmium for different species of fish is from 2 to 20 mg/l. However, the toxic effects of these heavy metals are reduced by the increased level of alkalinity in water (FAO, 1993).

Comparatively higher alkalinity obtained with the experimental ponds indicates poor or less toxic effects by heavy metals.

Comparatively higher value of ammonia-nitrogen was noted with higher stocking density pond (treatment T_3). A similar effect of higher stocking density of fish on NH_3-N concentration was also noted by Al-Harbi and Siddiqui (2000) and Ali *et al.* (2006) in a tank culture of tilapia. Stocking size and density of fish are the most important factors affecting fish growth and production in aquaculture pond (Zhu et al. 2011). Although increased stocking density of fish sometimes ensures more production, but often, results in deterioration of water quality which ultimately reduces the quality of the final product (Refaey et al., 2018). However, water quality parameters under different treatments were within more or less suitable range for aquaculture in pond according to Alikunhi (1957) and Swingle (1967). Observed values of water quality parameters were also found similar to the findings noted by Hossain (2011) and Hossain *et al.* (2021) while working on carp fattening in ponds under drought prone area. The concentration of two metals recorded during the study period was within the permissible level recommended by WHO (1993). The study also indicated that although the management practice of the experimental ponds was up to the mark, microbial load was found higher at treatment T_3 because of the deterioration of water by higher number of fishes. Microbial abundance may be increased with the overcrowding in the fish habitat (Sichewo *et al*., 2013).Fish production obtained in the experimental ponds were higher compared to the findings of several authors conducted their study on usual carp polyculture in pond. Talukder *et al.* (2017) reported a fish yield ranging from 1411.29 ± 25.19 to 3693.23 ± 69.37 kg/ha/6 months which was lower than the present findings. Overall findings indicated that treatment T_1 was found best in terms of suitable water quality, better fish growth and higher net profit of carp fattening in ponds of both Paba and Tanore upazilas. Findings clearly indicated that lower stocking density favored the fish growth. Fishes with higher stocking size and lower stocking density resulted in a higher growth and survival rate at treatment T_1. On the other hand, lower stocking size and higher density adversely affected the growth and survival of fish at treatment T_3. Almost similar observations are also reported well by Pouey *et al.* (2011) in their experiment. These findings were in agreement with Mridha *et al.* (2014) who also stated that fishes at high density become subjected to comparatively higher competition for food and space that causes physiological stress to fishes and results in lower growth performance. Findings also indicates that carp fattening is constrained by high feed cost (more than 50% of the total cost) and high lease value of the ponds (more than 10% of the total cost). Moreover, water addition cost (almost 1-2% of the total cost) is also increasing the total cost for fish production through carp fattening in drought prone area. Study conducted by Talukder et al. (2017) showed more than 50% of total cost of aquaculture expenditure were involved with feed cost. Therefore, apart from the appropriate selection of species combination and stocking density, low cost feed application selection is also important for the sustainability of this system. Considering all these facts and figures, further research can be initiated on the effect of supplementary feed on the production and economics of carp fattening in ponds with emphasis on GAP aspects.

11.3.4. SIS-Carp farming in homestead ponds

Major findings (in terms of water quality, fish growth and yield and economics) of the SIS-carp farming experiments conducted in Paba and Tanore upazilas are shown in Table 50 -58.

11.3.4.1.SIS-Carp farming in ponds of Paba upazila, Rajshahi

1.a. Water quality

Variations in the mean values of water quality parameters are shown in Table 51. No significant difference was found among the treatments for almost all the water quality parameters except dissolved oxygen, ammonia-nitrogen (NH_3-N) and total dissolved solids (TDS).

1.b. Fish growth

Variations among the treatments in growth performances (in terms of initial stocking weight, final weight, weight gain, SGR and survival rate) of fishes during culture period are shown in Table 52. Treatment T_1 varied more significantly (P <0.05) than others for the mean final weight, weight gain and survival rate in case of most of the species.

1.c. Fish yield

Variations in the fish yield under the treatments are shown in Table 53. All the treatments varied significantly (p<0.05) for the yield of fishes. Treatment T_3 varied more significantly than other treatments for the total fish yield. Fish yield with treatment T_3 was 40.25% higher than treatment T_1 and 9.37% higher than treatment $T_{2.}$

1.d. Economics of SIS-carp farming

Variations in the mean values of total cost, total return, net benefit and BCR are shown in Table 54. Treatments varied significantly (P <0.05) for the mean values of total cost, total return, net benefit and BCR. Feed was the major cost involving area with the treatments (76.19-81.97%). Net benefit with treatment T_1 was 35.60% higher than treatment T_1 and 18.5 3% higher than treatment $T_{3.}$

11.3.4.2. SIS-carp farming in ponds of Tanore upazila, Rajshahi

1.a. Water quality

Variations in the mean values of water quality parameters are shown in Table 55. No significant difference was found among the treatments for almost all the water quality parameters except, DO, pH and ammonia-nitrogen. Comparatively lower values of water transparency were noted with the treatments.

1.b. Fish growth

Variations among the treatments in growth performances (in terms of initial stocking weight, final weight, weight gain, SGR and survival rate) of fishes during culture period are shown in Table 56. Treatment T_1 varied more significantly (P <0.05) than others for the mean final weight, weight gain and survival rate in case of most of the species.

1.c. Fish yield

Variations in the fish yield under the treatments are shown in Table 57. All the treatments varied significantly (p<0.05) for the fish yields. Treatment T_3 varied significantly than other treatments. Fish yield with treatment T_3 was 44.24% higher than T_1 and 17.53% higher than T_2.

1.d. Economics of SIS-carp farming

Variations in the mean values of total cost, total return, net benefit and BCR are shown in Table 58. Treatments varied significantly (p<0.05) for the mean values of total cost, total return, net benefit and BCR. Feed was the major cost involving area with the treatments (75.54-81.48%). Net benefit with treatment T_2 was 33.47% higher than treatment T_1 and 5.16% higher than T_3.

Comparatively higher values of ammonia-nitrogen and lower values of dissolved oxygen content were noted with higher density treatment (T3). Stocking density is well-known to be one of the important parameters in fish culture as it directly affects water quality, growth, survival and production. The problems of intensive catfish farming are encountered as higher investment, lower survival rates, smaller harvesting sizes and higher feed conversion ratio (FCR) with the increase of stocking densities, deterioration of water quality with higher level of unionized ammonia (0.17-0.2 mg l^{-1}) (Rahman *et al.*, 2014). Comparatively lower values of water transparency with the treatments might be due to the general phenomenon like higher clay turbidity of the ponds under drought prone barind area (Hossain, 2011). However, water quality parameters were found more or less within the suitable limit for SIS-carp farming (Alikunhi, 1957 and Boyd, 1998). Mondol *et al.* (2018) recorded temperature range of 27.53 to 29.38°C, alkalinity ranging from 87.85 to 102.61 mg/l and pH value from 7.70 to 8.06 in ponds of carp-SIS polyculture system. Fish growth and yield were also comparable to the findings of Harun-Ur-Rashid *et al.* (2021) while working on SIS-carp polyculture in ponds under drought prone area. Overall findings indicated that treatment T_2 was found best in terms of water quality, growth and economics of SIS-carp farming in homestead ponds of both Paba and and Tanore upazilas. It may be noted that feed cost is found one of the major problems while promoting SIS-carp farming in homestead ponds especially by the poor peoples. Therefore, considering all these facts and figures, further research can be initiated on the effect of supplementary feed on the production and economics of Magur based carp polyculture in homestead ponds.

Table 40. Water quality under different treatments of carp fattening in ponds of Paba upazila, Rajshahi during study period (July-December, 2019)

Water quality	Treatments			F-value	P-value
	T_1	T_2	T_3		
Temperature (°C)	30.22±0.17a	30.42±0.14a	30.50±0.11a	0.98	0.43
DO (mg/l)	6.77±0.004a	6.20±0.11b	5.73±0.09c	40.84	0.00
pH	7.43±0.08a	7.49±0.05a	7.38±0.05a	0.74	0.51
Alkalinity (mg/l)	144.67±1.36a	142.72±2.39a	146.78±3.20a	0.69	0.54
Transparency (cm)	27.56±0.14a	26.78±0.242a	26.06±0.47a	1.34	0.33
NH3-N (mg/l)	0.02±0.001a	0.03±0.006a	0.04±0.005a	2.65	0.15
TDS (mg/l)	651.44±3.49a	655.56±13.46a	663.05±10.15a	0.35	0.72
CO_2 (mg/l)	1.65±0.14a	1.72±0.18a	1.70±0.04a	0.07	0.93
Plankton cell	441718.66±2579.64a	374268.00±1239.86b	282938.67±16628.96c	17.39	0.003

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 41. Fish growth under different treatments of carp fattening in ponds of Paba upazila, Rajshahi during study period (July-December, 2019)

Species	Treatment	Initial weight (g)	Final weight (g)	Weight gain (gd^{-1})	SGR (%, bwd^{-1})	Survival rate (%)
G.catla	T_1	410.00±2.88a	2911.00±20.98a	13.89±0.10a	1.07±0.00b	93.14±0.067a
	T_2	267.67±1.45b	1846.66±8.11b	8.77±0.04b	1.08±0.00b	88.68±1.72a
	T_3	205.33±.33c	1639.33±8.83c	7.96±0.03c	1.15±0.00a	80.84±3.24b
F value		0.00	0.00	0.00	0.00	0.01
P value		1917.07	2390.29	2320.55	181.83	8.34
H. molitrix	T_1	330.66±1.20a	2861.66±13.01a	14.06±0.07a	1.19±0.00c	91.52±2.11a
	T_2	221.33±1.85b	2180.00±5.50b	10.88±0.03b	1.27±0.00b	87.28±2.89a
	T_3	166.33±0.88c	1926.00±2.64c	9.77±0.01c	1.36±0.00a	77.40±2.45b
F value		3704.49	3396.53	1841.57	299.16	8.33
P value		0.00	0.00	0.00	0.00	0.02
L. rohita	T_1	301.66±1.20a	1674.33±6.88a	7.62±0.04a	0.95±0.00c	91.04±2.32a
	T_2	200.00±0.57b	1451.66±7.26b	6.95±0.03b	1.10±0.00b	85.28±0.78b
	T_3	151.33±0.88c	1278.33±19.34c	6.26±0.11c	1.18±0.01a	78.87±1.45c
F value		6907.43	249.23	87.63	267.91	13.64
P value		0.00	0.00	0.00	0.00	0.01
C. mrigala	T_1	379.66±0.88a	1551.00±7.37a	6.45±0.04a	0.77±0.00b	91.42±2.57a
	T_2	251.66±1.76b	142.00±2.51b	5.16±0.02b	0.85±0.00a	86.74±2.01ab
	T_3	190.66±1.45c	917.33±8.19c	4.03±0.04c	0.87±0.01a	81.55±0.68b
F value		4652.16	2300.43	1006.29	90.60	6.56
P value		0.00	0.00	0.00	0.00	0.03
C. carpio	T_1	310.33±0.88a	1586.33±10.41b	7.08±0.06b	0.90±0.00b	94.33±1.36a
	T_2	206.00±2.08b	1198.66±12.71a	5.51±0.07a	0.97±0.01a	86.30±0.96b
	T_3	155.33±1.20c	932.66±8.87ab	4.31±0.05ab	0.99±0.01ab	81.37±1.01c
F value		2858.45	928.82	449.41	31.46	33.82
P value		0.00	0.00	0.00	0.00	0.00

Figures bearing common letter(s) in a column do not differ significantly (p>0.05)

Table 42. Fish yield (kg/ha/6 months) under different treatments of carp fattening in ponds of Paba upazila, Rajshahi during study period (July-December, 2019)

Species	Treatments			F-value	P-value
	T_1	T_2	T_3		
G. catla	1477.38±4.77a	1319.02±24.15b	1438.42±71.35ab	3.58	0.04
H. molitrix	791.72±19.86b	872.83±35.38ab	916.50±30.89a	4.54	0.04
L. rohita	905.95±26.91c	1154.32±16.68b	1270.63±46.80a	32.59	0.00
C. mrigala	495.94±16.98b	558.68±18.40a	536.84±1043ab	4.13	0.04
C. carpio var. specularis	307.26±7.66a	321.91±9.33a	313.35±8.87a	0.72	0.52
All species	3978.28±20.61c	4226.77±82.83b	4475.75±73.33a	14.65	0.01

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 43. Economics of carp fattening in pond (1 ha) of Paba upazila, Rajshahi for six months culture period (July-December, 2019)

Items	Treatments			F-value	P-value
	T_1	T_2	T_3		
Variable cost (BDT/ha)					
Seed	119944.63±395.24a	115597.58±157.92b	113315.62±785.48c	42.62	0.00
Feed	466118.56±1399.84b	487103.74±4677.236a	497323.32±2791.59a	24.01	0.01
Fixed cost (BDT/ha)					
Lease value	123500.00±0.00a	123500.00±0.00a	123500.00±0.00a	-	-
Water (pump)	10000.00±0.00a	10000.00±0.00a	10000.00±0.00a	-	-
Lime	11799.00±0.00a	11799.00±0.00a	11799.00±0.00a	-	-
Fertilizer	23809.00±0.00a	23809.00±0.00a	23809.00±0.00a	-	-
Labour	55000.00±0.00a	55000.00±0.00a	55000.00±0.00a	-	-
Harvest	15500.00±0.00a	15500.00±0.00a	15500.00±0.00a	-	-
Total cost (BDT/ha)	825671.20±1780.45b	842309.32±4775.98a	850246.95±3037.69a	13.40	0.01
Total return (BDT/ha)	1164619.24±5999.84a	1049201.42±16066.49b	1014485.51±13160.75b	39.65	0.00
Net benefit (BDT/ha)	338948.03±5122.49a	206892.09±11291.49b	164238.55±10370.23c	95.26	0.00
CBR	0.41±0.01a	0.25±0.01b	0.19±0.01c	123.20	0.00

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 44. Water quality under different treatments of carp fattening in ponds of Tanore upazila, Rajshahi during study period (July-December, 2019)

Water quality	Treatments			F-value	P-value
	T_1	T_2	T_3		
Temperature (°C)	29.45±.53a	29.80±0.11a	29.87±0.17a	0.47	0.64
DO (mg/l)	6.72±0.32a	6.11±0.5ab	5.88±0.11b	4.69	0.04
pH	7.84±0.06a	7.42±0.08a	7.55±0.07a	1.2	0.34
Alkalinity (mg/l)	123.66±2.65a	120.38±2.87a	120.44±3.80a	0.35	0.71
Transparency (cm)	25.27±0.70a	24.55±0.38a	23.77±0.38a	0.57	0.58
NH3-N (mg/l)	0.02±0.0005a	0.02±0.0009a	0.03±0.0075a	0.66	0.54
TDS (mg/l)	677.11±5.98a	691.50±4.03a	699.88±12.03a	2.02	0.21
CO_2 (mg/l)	1.65±0.14a	1.72±0.18a	1.80±0.09a	0.25	0.78
Plankton cell	191295.00±10712.25a	157634.67±6246.83a	123570.00±11593.38b	11.93	0.01

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 45. Fish growth under different treatments of carp fattening in ponds of Tanore upazila, Rajshahi during study period (July-December, 2019)

Species	Treatment	Initial weight (g)	Final weight (g)	Weight gain (gd^{-1})	SGR (%, bwd^{-1})	Survival rate (%)
G.catla	T_1	402.66±3.92a	2815.66±2.33a	13.40±0.02a	1.08±0.01b	92.41±0.52a
	T_2	162.33±1.45b	1835.00±6.92b	8.73±0.04b	1.08±0.00b	87.95±1.41a
	T_3	103.00±3.05c	1619.33±7.62c	7.86±0.04c	1.15±0.01a	80.34±3.10b
F value		1172.98	1093.7	5802.35	42.54	9.37
P value		0.00	0.00	0.00	0.00	0.01
H. molitrix	T_1	334.00±2.64a	2771.33±11.25a	13.54±0.04a	1.17±0.00c	90.94±2.05a
	T_2	224.00±1.52b	2119.00±5.19b	10.52±0.03b	1.24±0.00b	86.12±2.61a
	T_3	169.66±0.66c	1898.33±10.13c	9.60±0.05c	1.34±0.00a	76.68±2.21b
F value		2150.67	2409.54	1972.34	947.58	9.88
P value		0.00	0.00	0.00	0.00	0.01
L. rohita	T_1	301.66±1.20a	1603.66±8.76a	7.23±0.04a	0.92±0.00c	90.55±1.65a
	T_2	202.00±1.52b	1371.66±9.27b	6.49±0.05b	1.06±0.01b	84.68±0.84b
	T_3	153.00±1.52c	1211.33±8.95c	5.87±0.05c	1.14±0.01a	78.52±1.66c
F value		2817.50	1168.11	1.37	0.04	108.62
P value		0.00	0.00	0.00	0.00	0.00
C. mrigala	T_1	377.66±0.33a	1517.00±6.65a	6.32±0.04a	0.77±0.00c	90.04±2.50a
	T_2	249.33±2.72b	1080.00±10.69b	4.61±0.07b	0.81±0.01b	85.68±1.72ab
	T_3	188.00±2.00c	886.00±8.96c	3.87±0.04c	0.86±0.00a	80.58±0.63b
F value		2431.93	1322.29	563.00	4046	6.95
P value		0.00	0.00	0.00	0.00	0.02
C. carpio	T_1	308.00±0.58a	1496.00±10.40a	6.60±0.06a	0.87±0.00b	92.14±0.90a
	T_2	206.00±0.58b	1158.33±8.74b	5.29±0.4b	0.95±0.00a	85.51±1.72ab
	T_3	153.66±067c	898.66±7.31c	4.13±0.04c	0.98±0.01a	80.79±1.46b
F value		1663.70	1129.72	595.63	116.05	16.46
P value		0.00	0.00	0.00	0.00	0.00

Figures bearing common letter(s) in a rowdo not differ significantly (p>0.05)

Table 46. Fish yield (kg/ha/6 months) under different treatments of carp fattening in ponds of Tanore upazila, Rajshahi during study period (July-December, 2019)

Species	Treatments			F- value	P- value
	T_1	T_2	T_3		
G. catla	1412.10±7.08a	1301.73±30.30a	1410.38±73.21a	1.89	0.23
H. molitrix	756.46±19.52b	831.07±31.67ab	890.02±30.13a	5.86	0.03
L. rohita	852.31±13.96c	1066.85±3.21b	1183.27±41.23a	44.37	0.00
C. mrigala	476.45±20.56a	487.93±9.41a	506.46±5.78a	1.26	0.34
C. carpio var. specularis	277.23±2.55b	305.00±10.14a	296.98±3.92ab	4.99	0.04
All species	3774.57±29.67b	3992.91±75.81b	4287.13±88.07a	13.79	0.01

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 47. Economics of carp fattening in pond (1 ha) of Tanore upazila, Rajshahi for six months culture period (July-December, 2019)

Items	Treatments				
Variable cost (BDT/ha)	T_1	T_2	T_3	F value	P value
Seed	119944.63±395.24a	115597.58±157.62b	113315.62±785.48c	42.62	0.00
Feed	455662.03±3331.57b	482341.92±1882.29a	490226.39±3975.41a	32.33	0.00
Fixed cost (BDT/ha)					
Lease value	101150.00±0.00 a	101150.00±0.00 a	101150.00±0.00 a	-	-
Water(pump)	10000.00±0.00 a	10000.00±0.00 a	10000.00±0.00 a	-	-
Lime	13319.00±0.00a	13319.00±0.00a	13319.00±0.00a	-	-
Fertilizer	23809.00±0.00a	23809.00±0.00a	23809.00±0.00a	-	-
Labour	55000.00±0.00 a	55000.00±0.00 a	55000.00±0.00 a	-	-
Harvest	15000.00±0.00 a	15000.00±0.00 a	15000.00±0.00 a	-	-
Total cost (BDT/ha)	794384.67±3668.79b	816717.50±1969.20a	822320.02±4507.97a	17.40	0.00
Total return (BDT/ha)	1164619.24±5999.84a	1049201.41±16066.49b	1014485.50±13160.75b	39.65	0.00
Net profit (BDT/ha)	339452.62±3816.53a	201567.22±12412.98b	167110.32±12702.81b	75.60	0.00
BCR	0.43±0.01a	0.25±0.01b	0.20±0.01c	93.37	0.00

Figures bearing common letter(s) in a row do not differ significantly (p >0.05)

Table 48. Concentration of pathogenic bacteria (MPN/g) in carp fattening ponds of Paba upazila, Rajshahi during study period (July-December, 2019)

Treatment / Bacteria	T_1	T_2	T_3	F value	P value
Soil					
Total coliform	186.66±52.38a	203.33±23.33a	320..±73.71a	1.81	0.24
Total fecal	128.33±26.82b	124.33±19.46b	173.33±35.27a	0.94	0.43
Water					
Total coliform	60.66±9.38a	86.33±17.13a	115.00±21.79a	2.58	0.15
Total fecal	29.00±5.194b	42.66±10.80a	60.66±9.38ba	3.26	0.11

Figures in a row bearing common letters do not differ significantly (p>0.05)

Table 49. Concentration of pathogenic bacteria (MPN/g) in carp fattening ponds of Tanore upazila, Rajshahi during study period (July-December, 2019)

Treatment / Bacteria	T_1	T_2	T_3		F value	P value
Soil						
Total coliform	60.66± 9.38b	86.33±17.13b	143.33±12.01a		10.21	0.01
Total faecal	30.66±6.69b	45.66±9.20ab	86.33±17.13a		5.88	0.03
Water						
Total coliform	12.06±3.31a	14.46±1.26a	20.66±5.69a		2.30	0.18
Total faecal	8.20±11.44b	10.13±2.01b	15.33±3.75a		6.29	0.03

Figures in a row bearing common letters do not differ significantly (p>0.05).

Table 50. Heavy metal concentration in pond water and fish feed under carp fattening system

Heavy metal	Source	
	Pond water (ppm)	Fish feed (ppm)
Lead (Pb)	0.0029±0.00	0.006±0.00
Cadmium (Cd)	0.023±0.00	0.014±0.00

Table 51. Water quality under different treatments of SIS-carp farming in ponds under Paba upazila, Rajshahi during study period (July-December, 2019)

Water quality	Treatments			F-value	P-value
	T_1	T_2	T_3		
Temperature (°C)	30.33±0.00[a]	30.18±1.18[a]	28.62±1.56[a]	1.08	0.40
DO (mg/l)	6.05±0.03[a]	5.50±0.00[b]	5.19±0.14[c]	26.00	0.00
pH	7.34±0.10[a]	7.20±0.06[a]	7.35±0.13[a]	0.98	0.43
Alkalinity (mg/l)	120.11±3.27[a]	114.66±1.20[a]	121.72±2.60[a]	2.16	0.19
Transparency (cm)	26.00±0.33[a]	25.27±0.61[a]	25.88±0.77[a]	0.56	0.59
NH3-N (mg/l)	0.02±0.00[b]	0.03±0.00[b]	0.06±0.02[a]	1.62	0.04
TDS (mg/l)	633.55±13.80[b]	670.27±7.79[a]	666.94±2.16[a]	4.83	0.27

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 52. Fish growth under different treatments of SIS-carp farming in ponds under Paba upazila, Rajshahi during study period (July-December, 2019)

Species	Treatment	Initial weight (g)	Final weight (g)	Weight gain (g/6months)	SGR (%, bwd^{-1})	Survival rate (%)
C .batrachus	T_1	1.10±0.01a	125.86±2.29a	124.76±2.30a	2.63±0.15c	90.04±2.57a
	T_2	0.55±0.00b	110.06±4.15b	109.51±4.16b	2.93±0.02b	83.84±1.43a
	T_3	0.37±0.00c	100.63±4.28b	100.26±4.28b	3.11±0.02a	68.67±2.26b
F value		23.49	11.91	11.21	139.26	26.41
P value		0.00	0.01	0.01	0.00	0.00
G. catla	T_1	202.33±1.45a	899.33±8.68a	697.00±10.11a	0.83±0.01a	83.80±3.06a
	T_2	201.66±4.40a	737.00±10.59b	635.33±7.31b	0.79±0.01b	75.30±3.39b
	T_3	203.66±2.40a	792.00±5.13c	588.33±7.26c	0.75±0.00c	69.63±2.57b
F value		0.11	40.70	42.72	17.57	5.54
P value		0.85	0.00	0.00	0.00	0.04
H. molitrix	T_1	211.66±2.02a	1320.33±22.36a	1108.66±22.39ab	1.02±0.01a	82.18±1.99a
	T_2	211.00±1.15a	1240.66±18.02b	1029.66±16.95b	0.98.±0.01ab	75.70±1.18b
	T_3	209.66±2.72a	1142.00±25.42b	972.33±26.95b	0.96±0.02b	70.37±1.24c
F value		0.24	9.27	9.83	5.66	15.10
P value		0.79	0.01	0.01	0.04	0.01
L. rohita	T_1	103.33±1.20a	763.66±11.28a	660.33±12.46a	1.11±0.01a	82.18±4.92a
	T_2	102.66±1.45a	726.00±18.44ab	623.33±19.87ab	1.08±0.02ab	74.08±3.71a
	T_3	104.00±2.00a	687.66±7.31b	583.67±5.48b	1.04±0.01b	72.46±3.45a
F value		0.17	8.31	7.59	4.00	1.62
P value		0.85	0.02	0.02	0.07	0.27

Figures bearing common letter(s) in a column do not differ significantly (p>0.05)

Table 53. Fish yield (kg/ha/6 months) under different treatments of SIS-carp farming in ponds under Paba upazila, Rajshahi during study period (July-December 2019)

Species	Treatments			F- value	P- value
	T_1	T_2	T_3		
C.batrachus	4155.53±94.37c	6789.41±165.90b	7632.78±339.25a	65.13	0.00
H. molitrix	441.91±21.82a	359.57±1.95b	307.27±9.29c	20.73	0.00
G. catla	136.11±5.78a	106.00±8.16b	85.87±4.38b	16.06	0.00
L. rohita	129.36±8.33a	107.16±3.08b	97.37±5.89b	7.08	0.03
All species	4852.92±111.14b	7362.14±143.16a	8123.30±347.24a	53.92	0.00

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 54. Economics of SIS-carp farming in pond (1 ha) under Paba upazila, Rajshahi for six months culture period (July-December, 2019)

Items	Treatments			F- value	P- value
	T_1	T_2	T_3		
Variable cost(BDT/ha)					
Seed	112151.99±172.08c	167652.89±79.86b	186212.47±186.20a	6304.53	0.00
Feed	554116.00±6394.70c	868780.00±11021.85b	1114652.00±18433.05a	466.44	0.00
Fixed cost(BDT/ha)					
Lime	12330.00±0.00a	12330.00±0.00a	12330.00±0.00a	-	-
Fertilizer	4467.00±0.00a	4467.00±0.00a	4467.00±0.00a	-	-
Labour	23050.00±0.00a	23050.00±0.00a	23050.00±0.00a	-	-
Harvest	19100.00±0.00a	19100.00±0.00a	19100.00±0.00a	-	-
Total cost (BDT/ha)	727214.99±6472.24c	1095379.79±10970.51b	1359811.47±18399.18a	604.71	0.00
Total return (BDT/ha)	1779610.33±39610.78b	2729652.77±64481.50a	2691190.25±11610.69a	45.04	0.00
Net benefit (BDT/ha)	1052395.34±35493.58c	1634272.87±55952.2a	1331378.78±10053.37b	17.52	0.00
BCR	1.44±0.04a	1.49±0.04a	0.97±0.06b	31.91	0.01

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 55. Water quality under different treatments of SIS-carp farming in ponds under Tanore upazila, Rajshahi during study period (July-December, 2019)

Water quality	Treatments			F-value	P- value
	T_1	T_2	T_3		
Temperature (°C)	29.62±0.23a	29.90±0.31a	29.51±0.42a	0.36	0.70
DO (mg/l)	6.00±0.11a	5.72±0.04ab	5.46±0.07b	10.20	0.01
pH	7.56±0.03b	7.00±0.03a	7.01±0.05a	4.42	0.04
Alkalinity (mg/l)	87.22±1.44a	94.00±0.41a	90.83±1.07a	10.14	0.20
Transparency (cm)	27.33±0.09a	26.22±0.74a	26.83±0.50a	2.49	0.16
NH3-N (mg/l)	0.02±0.00a	0.03±0.00a	0.03±0.01a	2.08	0.01
TDS (mg/l)	228.83±5.91a	264.44±5.64a	272.50±5.62a	2.30	0.18

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 56. Fish growth under different treatments of SIS-carp farming in ponds under Tanore upazila, Rajshahi during study period (July-December, 2019)

Species	Treatment	Initial weight (g)	Final weight (g)	Weight gain (g/6 months)	SGR (%, bwd^{-1})	Survival rate (%)
C. batrachus	T_1	1.07±0.01a	121.02±3.64a	119.94±3.63a	2.62±0.01c	88.13±1.80a
	T_2	0.53±0.01b	106.54±2.34b	106.00±2.34b	2.94±0.01b	79.59±1.20b
	T_3	0.35±0.01c	100.41±2.36b	100.05±2.34b	3.13±0.01a	69.95±2.08c
F value		1633.06	13.80	12.87	360.14	27.40
P value		0.00	0.01	0.01	0.00	0.00
G.catla	T_1	200.33±0.33a	876.00±17.34a	675.66±17.64a	0.82±0.01a	83.40±2.83a
	T_2	201.33±2.33a	808.66±8.17b	607.33±8.25b	0.77±0.01a	74.08±5.02ab
	T_3	201.66±2.60a	858.66±18.36b	557.00±8.87b	0.73±0.01b	68.42±1.23b
F value		0.11	14.75	14.46	11.25	4.92
P value		0.89	0.01	0.01	0.01	0.04
H. molitrix	T_1	213.00±1.52a	1320.33±22.36a	1107.33±22.98ab	1.01±0.01a	81.51±1.31a
	T_2	214.33±0.88a	1240.66±18.02b	1026.33±17.75ab	0.97±0.01b	75.16±1.78a
	T_3	212.00±3.51a	1182.00±24.42b	970.00±26.82b	0.95±0.02b	69.70±1.75a
F value		0.26	9.81	8.54	4.25	13.11
P value		0.75	0.01	0.02	0.04	0.01
L. rohita	T_1	101.33±0.33a	727.00±11.23a	625.66±11.02a	1.09±0.01a	81.37±4.92a
	T_2	101.66±0.88a	700.66±8.68ab	599.00±8.50ab	1.07±0.01ab	73.14±3.50a
	T_3	100.66±0.88a	667.67±11.40b	567.00±12.28b	1.05±0.01b	71.65±3.24a
F value		0.46	7.98	7.50	0.50	1.74
P value		0.64	0.02	0.02	0.06	0.25

Figures bearing common letter(s) in a column do not differ significantly (p>0.05)

Table 57. Fish yield (kg/ha/6 months) under different treatments of SIS-carp farming in ponds under Tanore upazila, Rajshahi during study period (July-December, 2019)

Species	Treatments			F-value	P-value
	T_1	T_2	T_3		
C.batrachus	3917.03±201.82c	6243.19±153.68b	7768.87±299.77a	73.19	0.00
H. molitrix	426.70±17.58a	354.51±4.35b	302.02±8.96c	28.79	0.00
G. catla	130.96±3.15a	98.43±11.14b	78.34±9.11b	14.59	0.01
L. rohita	121.18±9.79a	101.42±5.50ab	93.45±7.08b	3.47	0.10
All species	4595.66±206.16c	6797.56±157.71b	8242.67±300.8a	64.10	0.00

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 58. Economics of SIS-carp farming in pond (1 ha) under Tanore upazila, Rajshahi for six months culture period (July-December 2019)

Items	Treatments			F-value	P-value
	T_1	T_2	T_3		
Variable cost(BDT/ha)					
Seed	112151.99±172.08c	167652.89±79.86b	186212.47±186.20a	6304.53	0.00
Feed	531109.33±4501.64c	816467.66±2073.33b	1082506.33±1677.08a	311.8	0.00
Fixed cost(BDT/ha)					
Lime	13230.00±0.00a	13230.00±0.00a	13230.00±0.00a	-	-
Fertilizer	4467.00±0.00a	4467.00±0.00a	4467.00±0.00a	-	-
Labor	23050.00.±0.00a	23050.00.±0.00a	23050.00.±0.00a	-	-
Harvest	19100.00±0.00a	19100.00±0.00a	19100.00±0.00a	-	-

Total cost (BDT/ha)	703108.33±4673.28c	1043967.56±2071.05b	1328565.81±1670.21a	403.00	0.00
Total return (BDT/ha)	1661132.58±7997.84b	2484050.05±5905.93a	2694334.80±1002a	44.87	0.00
Net benefit (BDT/ha)	958024.25±7641.71b	1440082.49±6235.17a	1365768.99±8949.86a	11.39	0.01
BCR	1.36±0.10a	1.38±0.06a	1.02±0.06b	6.16	0.03

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

11.4. Optimization of stocking density for carp fattening in ponds in coastal areas by component 2 (PSTU) in 2019

1.a. Physico-chemical parameter of water

The physico-chemical parameters of water were recorded the environmental conditions under which the fish were cultured during the study period. The physico-chemical parameter such as water temperature (^{0}C), pH, dissolve oxygen (mg/l), carbon-di-oxide (mg/l), total dissolve solids (mg/l), ammonia (mg/l), nitrate (mg/l), alkalinity (mg/l) during the experimental period are shown in the table 59.

Table 59. Water quality parameters for carps in the experimental ponds (mean ± SD)

Parameters	**Treatment**		
	T_1	T_2	T_3
Temperature (^{0}C)	27.45±0.53	27.86±0.57	28.10±0.59
DO (mg/l)	7.07±0.36	7.28±0.58	6.92±0.78
pH	7.17±0.19	7.21±0.33	7.12±0.28
TDS (mg/l)	215.22±65.85^a	140.44±40.70^b	174.46±50.37^{ab}
CO_2 (mg/l)	12.73±3.10	11.33±3.70	11.47±4.21
Alkalinity (mg/l)	113.33±21.79	109.07±27.39	115.93±31.84
Nitrate (mg/l)	0.26±0.06	0.3±0.10	0.25±0.08
Ammonia (mg/l)	0.01±0.006	0.00±0.00	0.00±0.00

Water quality parameters were not significantly different among the treatments except TDS. All water quality parameters were found within the suitable range for carp fish culture.

1.b. Growth performance of fish

For the evaluation of production performance of carp fishes in three treatments in terms of final weight (g), specific growth rate (SGR percent per day), survival rate and production (kg/ha) were calculated and presented in Table 60.

Table 60. Growth performances of carps observed in different treatments

Parameters	Treatment		
	SD-10	**SD-15**	**SD-20**
Initial wt (g)	426±00	426±00	426±00
Final wt (g)	1696.00±553.38	1353.33±300.06	970.33±150.53
SGR (%/day)	0.56±0.13[a]	0.47±0.09[ab]	0.34±0.06[b]
Survival rate (%)	72.00±8.37[ab]	77.79±3.58[a]	62.86±7.17[b]
Production (kg/ha/270 d)	2941.92±589.44[ab]	3875.63±684.63[a]	2739.76±80.95[b]

SGR of carps were 0.56±0.13 %/day, 0.47±0.09 %/day and 0.34±0.06 %/day in SD-10, SD-15 and SD-20, respectively. SGR of carp was significantly higher in SD-10 compared to other treatments, where carp was stocked at the rate of 10 individual/decimal. Production of carp in treatments SD-10, SD-15 and SD-20 were found 2941.92±589.44 kg/ha, 3875.63±684.63 kg/ha and 2739.76±80.95kg/ha, respectively with higher production recorded in SD-15 which might be associated with higher survival rate of carp obtained in this treatment.

1.c. Economic analysis

The economic analysis of the experiment is shown in Table 61.Among three treatments, SD-10 was made Tk. 187388/ha net benefit then SD-15 was earned Tk. 173403/ha and SD-20 earned negative value. BCR was obtained 1.41, 1.26 and 0.68 in SD-10, SD-15 and SD-20, respectively. BCR was higher in SD-10 because of the lowest variable cost in SD-10 than the other treatments.

Table 61. BCR calculations for carps

Benefit-cost	**SD-10**	**SD-15**	**SD-20**
Total variable costs (Taka)	459834	679236	891066
Total revenue (Taka)	647222	852639	602747
Net benefit (return)	187388	173403	-288319
Benefit Cost Ratio (BCR)	1.41	1.26	0.68

11.5. Optimization of stocking density for farming of SIS fishes in homestead ponds under coastal area

1.a. Physico-chemical parameters of water

The physico-chemical parameter such as water temperature (^{0}C), pH, dissolve oxygen (mg/l), carbon-di-oxide (mg/l), total dissolve solids (mg/l), ammonia (mg/l), nitrate (mg/l), alkalinity (mg/l) during the experimental period are shown in the Table 62.

Table 62. Water quality parameters for Magur culture in the experimental ponds during the experimental period (mean ± SD)

Parameters	Treatment		
	SD-150	SD-300	SD-450
Temperature (^{0}C)	27.87±2.53	27.97±1.50	28.24±0.42
DO (mg/l)	7.10±0.18	6.95±0.21	7.15±0.29
pH	7.30±0.17	7.25±0.30	7.32±0.22
TDS (mg/l)	212.90±26.85	193.12±20.60	153.05±15.39
CO_2 (mg/l)	11.80±2.10	11.13±1.70	10.87±2.08
Alkalinity (mg/l)	108.73±35.79	112.00±37.23	110.73±51.34
Nitrate (mg/l)	0.26±0.09	0.28±0.10	0.25±0.07
Ammonia (mg/l)	0.00±0.00	0.00±0.00	0.00±0.00

Water quality parameters were not significantly different among the treatments. All water quality parameters were found within the suitable range for Magur culture.

1.b. Growth performance of Magur fish

The growth performance of Magur fishes in terms of initial weight (g), final weight (g), weight gain (g), specific growth rate(%) survival rate(%) and total production (kg/ha/270 days) are shown in Table 63.

Table 63. Growth performance of Magur in different treatments during the experimental period

Parameters	Treatment		
	SD-150	SD-300	SD-450
Initial weight (g)	1.20±0.00	1.20±0.00	1.20±0.00
Final weight (g)	195.00±10.00^a	175.00±10.00^b	125.00±10.00^c
Weight gain (g)	193.8±10.00^a	173.8±10.00^b	123.8±10.00^c
SGR (%/day)	1.89±0.02^a	1.84±0.02^a	1.72±0.03^b
Survival rate (%)	55.93±2.85^a	47.59±0.98^b	40.01±6.44^b
Production (kg/ha/270 d)	4047.37±408.52^b	6173.63±418.36^a	5513.25±453.62^a

Mean values with different superscript letters in each raw indicate significantly different (p<0.05).

Final weight (g), SGR (%/day) and survival rate (%) of Magur was significantly higher in SD-150 compared to other treatments, where Magur was stocked at the rate of 150 individual/decimal. Production of Magur in treatments SD-150, SD-300 and SD-450 were found 4047.37±408.52 kg/ha, 6173.63±418.36 kg/ha and 5513.25±453.62 kg/ha, respectively with higher production recorded in SD-300, where Magur was stocked at the rate of 300 individual/decimal.

1.c. Economic analysis

The economic analysis of the experiment is shown in Table 64.

Table 64. Benefit Cost Ratio (BCR) of different treatments of Magur in ponds under coastal area

Benefit-cost	SD-150	SD-300	SD-450
Total variable costs (Taka)	670083	966928	1208578
Total income (Taka)	971369	1481671	1323180
Net benefit return	301286	514743	114602
Benefit cost Ratio (BCR)	1.45	1.53	1.09

The total cost was highest in treatment SD-450 (Tk. 1208578) and the total income was highest in treatment SD-300 (Tk. 1481671). The highest net benefit return was found in treatment SD-300 (Tk. 514743) and the lowest in treatment SD-450 (Tk. 114602). However, the highest BCR was found in treatment SD-300.

11.6. Carp fattening experiment in ponds by component 1 (RU) in 2020

Major findings (in terms of water quality, fish growth and yield, economics and GAP aspects) of the carp fattening experiments conducted in Paba and Tanore upazilas are shown in Table 65-75.

11.6.1. Carp fattening in ponds of Paba upazila, Rajshahi

1.a. Water quality

Variations in the mean values of water quality parameters are shown in Table 65. No significant difference was found among the treatments for the mean water quality parameters. Comparatively higher value of dissolved oxygen and lower value of ammonia-nitrogen was found with treatment T_3 which received no regular feeding. Present findings clearly indicates that feeding restriction can play a significant role for improvement in water quality and it was reflected well while most of the parameters were found within suitable range for fish farming specially with treatment T_3 .

1.b. Fish growth

Variations among the treatments in growth performances (in terms of initial weight, final weight, daily weight gain, specific growth rate and survival rate) of fishes during culture period are shown in Table 66. Growth parameters of all the fish species did not vary significantly (p >0.05)with the treatments. Comparatively higher values of mean final weight and daily weight gain of fishes were found with regular feeding of factory feed treatment (T_1). Findings indicated that regular feeding of 100% factory feed favored the growth of fishes in treatment T_1.

1.c. Fish yield

Variations in the fish yield under the treatments are shown in Table 67. Treatments did not vary significantly (p>0.05) for the yield of different fish species. Comparatively higher yield was recorded with treatment T_1 during study. Fish yield with treatment T_1 (regular feeding of 100% factory feed) was 1.88% higher than treatment T_2 and 3.17% higher than treatment T_3.

1.d. Economics of carp fattening

Variations in the mean values of cost, net benefit and CBR are shown in Table 68. Significant difference (p<0.05) was found among the treatments for the mean values of total cost, total return, net benefit and CBR. Findings clearly indicated that restricted feeding reduced the feed cost to a greater extent (feed cost in treatment T_3 was 36.31% less than treatment T_1 and 22.77% less than treatment T_2. Net benefit with treatment T_3 was 28.89% higher than treatment T_1 and 19.49% higher than treatment $T_{2.}$

11.6.2. Carp fattening in ponds of Tanore upazila, Rajshahi

1.a. Water quality

Variations in the mean values of water quality parameters are shown in Table 69. No significant difference was found among the treatments for the mean water quality parameters. Comparatively higher value of dissolved oxygen and lower value of ammonia-nitrogen was found with treatment T_3 which received no regular feeding. Present findings clearly indicates that feeding restriction can play a significant role for improvement in water quality and it was reflected well while most of the parameters were found within suitable range for fish farming specially with treatment T_3 .

1.b. Fish growth

Variations among the treatments in growth performances (in terms of initial weight, final weight, daily weight gain, specific growth rate and survival rate) of fishes during culture period are shown in Table 70. Growth parameters of all the fish species did not vary significantly (P >0.05) with the treatments. Comparatively higher values of mean final weight and daily weight gain of fishes were found with regular feeding of factory feed treatment (T_1). Findings indicated that regular feeding of 100% factory feed favored the growth of fishes in treatment T_1.

1.c. Fish yield

Variations in the fish yield under the treatments are shown in Table 71. Treatments did not vary significantly (p>0.05) for the yield of different fish species. Comparatively higher yield was recorded with treatment T_1 during study. Fish yield with treatment T_1 (regular feeding of 100% factory feed) was 1.53% higher than treatment T_2 and 3.48% higher than treatment $T_{3.}$

1.d. Economics of carp fattening

Variations in the mean values of cost, net benefit and BCR are shown in Table 72. Significant difference (P<0.05) was found among the treatments for the mean values of total cost, net benefit and BCR. Findings clearly indicated that restricted feeding reduced the feed cost to a greater extent (feed cost in treatment T_3 was 27.48% less than treatment T_1 and 19.43% less than treatment T_2. Net benefit with treatment T_3 was 28.87% higher than treatment T_1 and 19.01% higher than treatment $T_{2.}$

11.6.3. GAP aspects of carp fattening ponds

GAP aspects in terms of pathogenic bacteria and heavy metal concentration are shown in Table 73-75. Bacterial load was found lower in water than that of the bottom soil (Table 73-74). On the other hand, no pathogenic bacteria was detected in the fish muscle. The less concentration of bacteria in water and no microbial existence in fish muscle clearly indicated a good environment and management of the ponds. Among the different treatments, bacterial load was comparatively higher with treatment T_1. Comparatively lower concentration of cadmium and lead was recorded with the treatments during study (Table 75).

11.6.4. Live fish transportation

Mean water quality and survival rate of fish are shown in Table 76. Significantly highest value of DO and lowest value of ammonia-nitrogen was recorded at end point with transporting lowest fish biomass (Treatment T_1). The higher DO content in treatment T1 might be due to the lower consumption of DO as respiration by the fishes. Lowest DO content with highest density was also noted well by Gomes *et al*. (2003) while working on live fish transportation. Inappropriate depuration and high density may cause severe stress to the fishes during transportation and deteriorate the water quality (Emata, 2000). Treatments varied significantly for ammonia level (at end point) in spite of having same depuration period of the harvested fishes for transportation. This might be due to the higher production of metabolic waste at higher densities. Dobsikova *et al.* (2009) stated that the elevated ammonia in the transport water may be attributed to the higher fish metabolic rate. Findings clearly indicated that fishes under treatment T_1 were less prone to stress and thereby found with high survival rate. The causes of mortality in fish transport generally include depletion of dissolved oxygen in ambient water due to respiration of fish, oxidation and excreted waste; accumulation of free carbon dioxide, sudden fluctuation in temperature, hyper activity and stress due to handling and confined space and physical injuries (Bolorunduro, 1995). Transporting fish at high densities resulted poor water quality and high fish mortality in this study. Present findings was also well supported with Ross and Ross (1999) reporting major fish stress at high densities during transportation.

11.6.4.1. Organoleptic study

Assessment results of the organoleptic study is shown in Table 77. Among the different treatments, treatment T1 (with less organic matter content; receiving no organic fertilizer; and including silver carp to control the plankton bloom) was found best in terms of meaty taste, species specific odor and firm texture.

Comparatively higher DO content and lower ammonia level was recorded with treatment T_3 which might be due to the effective utilization of the feed (i.e. no accumulation of organic matter in the pond bottom to produce or increase the harmful gas in water). Regular feeding of factory feed especially in treatment T_1 resulted wastage of feed and thereby resulted ammonia production (Wilson, 2002). However, water quality parameters under different treatments were within more or less suitable range for aquaculture in pond according to Alikunhi (1957). Heavy metal concentrations recorded during the study period were within the acceptable level recommended by WHO (1993). The study also indicated that although the management practice of the experimental ponds was up to the mark, microbial load was found comparatively higher at treatment T_3(regular feeding of factory feed) which might be due to the presence of uneaten feed by the fishes resulting water pollution and thereby favoring microbial growth. Assumption almost agreed with Joseph *et al*. (2017) reporting excess growth of bacteria in organic substance rich water through feed and fertilization. Overall findings indicated that treatment T_1 was found best in terms of suitable water quality, moderate fish yield and highest net profit of carp fattening in ponds of both Paba and Tanore upazilas. This study used 25% protein content in diet and growth and yield of fish obtained were also almost comparable with the findings observed by Hossain *et al.* (2021) while working on carp fattening in ponds under drought prone area. Findings clearly indicated that use of factory feed resulted in higher feed cost and thereby the higher total cost in treatment T_1. Findings also indicates that carp fattening is constrained by high feed cost and it may be mitigated by reduced use of factory feed and introducing home- made feed with feed restriction. High feed cost in fish farming was also noted well with Talukder *et al*. (2017) who showed more than 50% of total cost of aquaculture expenditure and with Sayed *et al.* (2020) reporting the feed cost as 64-73% of the total cost. This study indicated that inclusion of 100% commercial feed might be beneficial for increasing fish growth and yield a little bit, but substitution of this commercial feed with handmade feed and following the strategy of feeding restriction was more profitable and economically feasible. In fact feed and feeding strategy with treatment T1 of the present study was found as effective technique to reduce the feed cost, maximize feed utilization and improve the production and profit. Efficient management of feeding can play an important role in successful culture of carps in ponds (Liu *et al.*, 2011). Apart from the suitable species combination, stocking density and feeding strategy suitable live fish transportation system is also considered important for obtaining good water quality, reducing fish mortality and thereby sustainability of the system (Grover *et al*, 2020). Findings of the transportation study clearly indicated that transporting lower fish biomass along with continuous aeration and water exchange (once during transport) improved the water quality and increased the fish survival. Organoleptic study of harvested carps indicated that fish produced under good environment with good management practices was found with natural taste. Findings indicated that ponds with more organic matter content with exclusion of appropriate species to control the plankton bloom (produced through the use of feed and fertilizer) failed to produce fish of natural taste. Therefore, maintaining appropriate species combination, stocking density, feeding strategy and GAP aspects are considered important for sustainability of carp fattening in ponds under drought prone area. It may also be concluded that GAP not only produced safe fish but also tasty fish in carp fattening ponds under drought prone area.

11.6.5. SIS-Carp farming in homestead ponds

Major findings (in terms of water quality, fish growth and yield and economics) of the SIS-carp farming experiments conducted in Paba and Tanore upazilas are shown in Table 78 – 85.

11.6.5.1.SIS-Carp farming in ponds of Paba upazila, Rajshahi

1.a. Water quality

Variations in the mean values of water quality parameters are shown in Table 78. No significant difference was found among the treatments for almost all the water quality parameters except ammonia-nitrogen (NH_3-N).

1.b. Fish growth

Variations among the treatments in growth performances (in terms of initial stocking weight, final weight, weight gain, SGR and survival rate) of fishes during culture period are shown in Table 79. Comparatively higher values of mean final weight, weight gain and survival of fishes were found with treatment T_1 (100% factory feed).

1.c. Fish yield

Variations in the fish yield under the treatments are shown in Table 80. All the treatments varied significantly (p<0.05) for the combined yield of fishes. Treatment T_1 varied more significantly than other treatments for the total fish yield. Fish yield with treatment T1was 4.01% higher than treatment T_1 and 14.17% higher than treatment $T_{3.}$

1.d. Economics of SIS-carp farming

Variations in the mean values of total cost, total return, net benefit and BCR are shown in Table 81. Treatments varied significantly (p<0.05) for the mean values of total cost, total return and BCR. Feed cost was 63.47% less than treatment T_1 and 25.81% less than treatment $T_{2.}$

11.6.6.SIS-carp farming in ponds of Tanore upazila, Rajshahi

1.a. Water quality

Variations in the mean values of water quality parameters are shown in Table 82. No significant difference was found among the treatments for almost all the water quality parameters except ammonia-nitrogen (NH_3-N).

1.b. Fish growth

Variations among the treatments in growth performances (in terms of initial stocking weight, final weight, weight gain, SGR and survival rate) of fishes during culture period are shown in Table 83. Comparatively higher values of mean final weight, weight gain and survival of fishes were found with treatment T_1 (100% factory feed).

1.c. Fish yield

Variations in the fish yield under the treatments are shown in Table 84. All the treatments varied significantly (p<0.05) for the combined yield of fishes. Treatment T_1 varied more significantly than other treatments for the total fish yield. Fish yield with treatment T1was 5.01% higher than treatment T_1 and 14.65% higher than treatment $T_{3.}$

1.d. Economics of SIS-carp farming

Variations in the mean values of total cost, total return, net benefit and BCR are shown in Table 85. Treatments varied significantly (p<0.05) for the mean values of total cost, total return and BCR. Feed cost was 63.82% less than treatment T_1 and 25.94% less than treatment $T_{2.}$

Comparatively lower ammonia level was recorded with treatment T_3 which might be due to the effective utilization of the feed (i.e. no accumulation of organic matter in the pond bottom to produce or increase the harmful gas in water). Appropriate feeding strategies can assist to minimize food wastage and to ensure the optimal production efficiency (Dwyer *et al*., 2002). However, water quality parameters under different treatments were within more or less suitable range for aquaculture in pond according to Boyd (1998).Mean values of the water quality parameters were almost comparable with the findings noted by Nabi *et al*. (2020) while working on SIS fish farming in homestead ponds under drought prone area. Overall findings indicated that treatment T_3 was found best in terms of water quality, growth and economics of SIS-carp farming in homestead ponds of both Paba and and Tanore upazilas. Dietary protein content is considered an important factor for biomass increase within shorter period in ponds with higher stocking density of catfishes. Mean weight gain of *C. batrachus* recorded in this study was found comparatively better than the weight gain recorded by Reza *et al.* (2021) using 28% protein containing diet. Hussain *et al.* (2008) recommended 30–35% protein content in diet for farming of *C. batrachus* in pond. Although yield of SIS fish and combined yield of SIS and carps were significantly higher in treatment T_1 but high feed cost with that treatment ultimately resulted lower CBR than other treatments. This study was done in homestead ponds by the distressed women by which sustainable production may not be maintained with the only use of high cost factory feed. Although protein rich factory feed plays important role for maximizing production under high stocking density in intensive farming but investment particularly for expensive artificial feeds can comprise more than 40-60% of the total variable costs (De Silva and Hasan, 2007) and in hence, selection of feed type and feeding strategy is considered important for feed based fish farming (Gelineau *et al*., 1998; Khan and Abidi, 2010) specially by the poor peoples. Therefore, reduced use of factory feed and introducing home–made feed with restricted feeding strategy was the appropriate technique for the promotion of SIS fish farming in homestead ponds under drought prone area.

Table 65. Water quality under different treatments of carp fattening in ponds of Paba upazila, Rajshahi

Water quality	Treatments			F-value	P-value
	T_1	T_2	T_3		
Temperature (°C)	30.90±0.03a	31.06±0.20a	31.21±0.05a	0.54	0.61
DO (mg/l)	6.73±0.06a	6.72±0.14a	6.98±0.06a	2.29	0.21
pH	7.78±0.10a	7.82±0.03a	7.95±0.12a	0.81	0.49
Alkalinity (mg/l)	155.83±4.09a	152.11±3.80a	153.00±2.94a	0.28	0.76
Transparency (cm)	26.66±0.25a	26.94±0.24a	26.44±0.48a	1.30	0.34
NH3-N (mg/l)	0.05±0.00a	0.04±0.00a	0.03±0.00a	3.59	0.09
TDS (mg/l)	670.66±7.17a	672.44±8.99a	661.33±4.27a	0.71	0.53
CO_2 (mg/l)	2.05±0.0.05a	1.99±0.06a	1.81±0.09a	3.26	0.11
Plankton (cells/l)	388683.33±8649.19a	395050.00±20000.00a	366850.00±9999.00a	1.14	0.38

Figures bearing common letter(s) in a row do not differ significantly (p >0.05)

Table 66. Fish growth under different treatments of carp fattening in ponds of Paba upazila, Rajshahi

Species	Treatment	Initial weight (g)	Final weight (g)	Weight gain (gd^{-1})	SGR (%, bwd^{-1})	Survival rate (%)
G. catla	T_1	419.66±2.02a	2876.33±67.53a	2456.66±66.62a	1.06±0.01a	92.03±1.19a
	T_2	431.33±4.17a	2867.00±6.45a	2435.66±63.53a	1.05±0.02a	91.54±0.59a
	T_3	427.00±6.11a	2820.66±46.49a	2393.66±46.20a	1.04±0.01a	91.67±1.09a
F value		1.77	0.25	0.29	0.66	0.06
P value		0.24	0.78	0.75	0.54	0.93
H. molitrix	T_1	359.00±3.78a	2828.66±26.20a	2479.66±29.80a	1.16±0.01a	91.90±0.40a
	T_2	356.00±5.56a	2807.33±54.89a	2451.33±56.26a	1.14±0.02a	90.55±1.81a
	T_3	358.33±1.20a	2802.00±8.88a	2443.66±9.59a	1.14±0.03a	93.25±1.17a
F value		1.51	0.15	0.26	0.89	1.12
P value		0.29	0.85	0.77	0.45	0.38
L. rohita	T_1	331.66±7.26a	1718.00±47.84a	1386.33±54.97a	0.91±0.02a	91.76±0.97a
	T_2	323.33±3.38a	1687.00±43.84a	1363.66±42.11a	0.92±0.01a	91.04±0.86a
	T_3	320.33±4.48a	1641.33±39.95a	1321.00±43.82a	0.90±0.02a	90.82±1.28a
F value		1.22	0.76	0.49	0.06	0.21
P value		0.35	0.50	0.63	0.94	0.81
C. mrigala	T_1	331.33±2.40a	1595.33±31.68a	1254.00±34.04a	0.85±0.01a	89.06±1.01a
	T_2	337.00±4.04a	1526.00±37.43a	1237.00±34.82a	0.86±0.01a	88.93±1.13a
	T_3	334.66±5.17a	1526.00±12.66a	1191.33±10.49a	0.84±0.01a	89.94±1.18a
F value		0.70	1.47	1.26	0.47	0.24
P value		0.53	0.30	0.34	0.64	0.79
C. carpio	T_1	334.66±3.28a	1721.66±53.73a	1387.00±55.24a	0.91±0.02a	89.47±1.68a
	T_2	340.66±5.98a	1694.66±37.48a	1354.00±32.74a	0.89±0.01a	90.82±1.05a
	T_3	344.66±4.80a	1664.66±41.55a	1320.00±45.76a	0.87±0.02a	92.98±0.95a
F value		1.10	0.40	0.54	1.02	2.30
P value		0.39	0.68	0.60	0.41	0.18

Figures bearing common letter(s) in a column do not differ significantly (p>0.05)

Table 67. Fish yield (kg/ha/6 months) under different treatments of carp fattening in ponds of Paba Upazila, Rajshahi during study period (July-December, 2020)

Species	Treatments			F- value	P- value
	T_1	T_2	T_3		
G. catla	1651.61±67.99a	1625.15±45.70a	1600.50±54.43a	0.20	0.82
H. molitrix	555.88±6.21a	540.33±23.71a	556.86±7.31a	0.39	0.69
L. rohita	922.71±43.73a	899.10±38.69a	867.76±41.23a	0.44	0.66
C. mrigala	533.01±7.26a	525.45±24.10a	512.58±4.79a	0.48	0.63
C. carpio var. specularis	257.62±1045a	296.21±11.60a	257.24±11.81a	0.00	0.99
All species	3960.84±104.89a	3886.27±128.581a	3834.95±91.48a	0.33	0.72

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 68. Economics of carp fattening in pond (1 ha)of Paba upazila, Rajshahi for six months culture period (July-December, 2020)

Items	Treatments			F-value	P-value
	T_1	T_2	T_3		
Variable cost(BDT/ha)					
Seed	110026.97±539.38a	110177.64±718.53a	109466.28±834.63a	0.28	0.76
Feed	477043.00±708.53a	429672.65±872.80b	349970.50±92.88c	9722.93	0.00
Fixed cost(BDT/ha)					
Lease value	125000.00±0.00	125000.00±0.00	125000.00±0.00	-	-
Water (pump)	11000.00±0.00	11000.00±0.00	11000.00±0.00	-	-
Lime	14300±0.00	14300±0.00	14300±0.00	-	-
Fertilizer	18420.00±0.00	18420.00±0.00	18420.00±0.00	-	-
Labour	54500.00±0.00	54500.00±0.00	54500.00±0.00	-	-
Harvest	16000.00±0.00	16000.00±0.00	16000.00±0.00	-	-
Total cost (BDT/ha)	826289.97±818.33a	779070.29±1504.59b	697656.78±783.49c	3521.81	0.00
Total return (BDT/ha)	1064168.72±24603.45a	1048381.13±28222.28a	1033175.15±22110.97a	0.38	0.69
Net benefit (BDT/ha)	237878.75±24508.08b	269310.84±27334.20ab	334518.37±22652.45a	3.91	0.04
BCR	0.28±0.03b	0.35±0.03b	0.48±0.03a	9.09	0.01

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 69. Water quality under different treatments of carp fattening in ponds of Tanore upazila, Rajshahi during study period (July-December, 2020)

Water quality	Treatments			F-value	P-value
	T_1	T_2	T_3		
Temperature (°C)	30.89±0.10a	31.04±0.19a	31.12±0.07a	0.74	0.51
DO (mg/l)	6.52±0.09a	6.50±0.07a	6.65±0.10a	0.84	0.47
pH	7.29±0.08a	7.22±0.04a	7.28±0.02a	0.38	0.69
Alkalinity (mg/l)	114.38±2.48a	116.83±3.58a	117.50±5.07a	0.18	0.84
Transparency (cm)	25.44±0.54a	25.55±0.58a	26.22±0.56a	0.55	0.60
NH3-N (mg/l)	0.04±0.01a	0.05±0.00a	0.03±0.01a	2.71	0.14
TDS (mg/l)	635.16±10.17a	640.33±7.37a	640.00±10.36a	0.09	0.91
CO_2(mg/l)	2.10±0.07a	2.05±0.03ab	1.89±0.03b	4.62	0.04
Plankton (cells/l)	189016.66±8879.76a	197050.00±19502.13a	167516.66±9864.09a	1.25	0.35

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 70. Fish growth under different treatments of carp fattening in ponds of Tanore upazila, Rajshahi during study period (July-December, 2020)

Species	Treatment	Initial weight (g)	Final weight (g)	Weight gain (gd^{-1})	SGR (%, bwd^{-1})	Survival rate (%)
G.catla	T_1	422.33±1.76a	2864.33±7.42a	2442.00±68.82a	1.06±0.01a	91.63±1.04a
	T_2	426.00±2.08a	2849.00±57.15a	2423.00±55.73	1.05±0.01a	91.00±0.97a
	T_3	433.66±2.90a	2805.00±10.96a	2371.33±11.83a	1.03±0.00a	91.09±1.45a
F value		0.31	0.34	0.50	2.14	0.08
P value		0.13	0.72	0.62	0.19	0.92
H. molitrix	T_1	346.00±5.56a	2788.00±28.58a	2442.00±28.21a	1.15±0.00a	93.52±1.01a
	T_2	353.66±6.17a	2762.33±31.31a	2408.66±34.16a	1.14±0.01a	92.17±2.70a
	T_3	357.66±2.72a	2763.33±19.36a	2404.66±16.75a	1.13±0.00a	93.79±3.42a
F value		1.37	0.30	0.56	1.60	0.11
P value		0.32	0.74	0.59	0.27	0.89
L. rohita	T_1	329.66±6.64a	1683.00±40.79a	1353.33±46.18a	0.90±0.02a	91.27±1.18a
	T_2	320.66±3.17a	1660.33±25.14a	1339.66±23.69a	0.91±0.01a	90.77±0.87a
	T_3	325.33±3.17a	1609.33±57.97a	1284.00±58.20a	0.88±0.02a	91.00±1.46a
F value		0.94	0.75	0.66	0.50	0.04
P value		0.44	0.51	0.54	0.62	0.95
C. mrigala	T_1	343.33±2.84a	1572.00±16.92a	1228.66±19.64a	0.84±0.01a	88.52±1.28a
	T_2	338.66±2.96a	1548.00±18.33a	1209.33±15.77a	0.84±0.00a	88.59±1.26a
	T_3	334.33±5.92a	1505.33±42.34a	1171.00±38.10a	0.83±0.01a	89.40±1.54a
F value		1.16	1.41	1.23	0.36	0.12
P value		0.37	0.31	0.35	0.70	0.88
C. carpio	T_1	342.33±2.40a	1659.00±54.09a	1316.66±55.95a	0.87±0.02a	89.87±1.42a
	T_2	337.00±6.65a	1647.33±46.24a	1310.33±44.09a	0.88±0.01a	91.63±0.88a
	T_3	340.33±5.78a	1604.00±39.03a	1263.66±3938a	0.86±0.02a	93.38±0.58a
F value		0.26	0.38	0.37	0.34	2.93
P value		0.77	0.69	0.70	0.72	0.12

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 71. Fish yield (kg/ha/6 months) under different treatments of carp fattening in ponds of Tanore upazila, Rajshahi during study period (July-December, 2020)

Species	**Treatments**			**F-value**	**P-value**
	T_1	T_2	T_3		
G. catla	1632.12±54.80a	1606.16±55.25a	1571.89±22.28a	0.41	0.67
H. molitrix	558.48±4.91a	541.67±23.53a	551.87±26.73a	0.16	0.85
L. rohita	894.67±45.45a	879.55±26.69a	843.03±24.61a	0.62	0.56
C. mrigala	517.67±2.69a	510.31±13.59a	499.21±9.43a	0.92	0.44
C. carpio var. specularis	284.03±17.45a	289.79±13.43a	285.94±10.05a	0.04	0.95
All species	3887.00±108.79a	3827.50±75.24a	3751.84±7.49a	0.78	0.49

Figures bearing common letter(s) in a row do not differ significantly (P >0.05)

Table 72. Economics of carp fattening in pond (1 ha) of Tanore upazila, Rajshahi for six months culture period (July-December, 2020)

Items	**Treatments**				
	T_1	T_2	T_3	**F value**	**P value**
Variable cost (BDT/ha)					
Seed	110273.56±656.01a	109367.89±273.50a	110478.57±529.20a	1.33	0.33
Feed	475881.50±451.73a	428366.40±848.34b	345121.70±63.56c	141.64	0.00
Fixed cost (BDT/ha)					
Lease value	101500.00±0.00	101500.00±0.00	101500.00±0.00	-	-
Water (pump)	12000.00±0.00	12000.00±0.00	12000.00±0.00	-	-
Lime	16200.00±0.00	16200.00±0.00	16200.00±0.00	-	-
Fertilizer	17380.00±0.00	17380.00±0.00	17380.00±0.00	-	-
Labour	54500.00±0.00	54500.00±0.00	54500.00±0.00	-	-
Harvest	16000.00±0.00	16000.00±0.00	16000.00±0.00	-	-
Total cost (BDT/ha)	803735.06+±691.68a	755314.29±891.28b	673180.27±589.69c	8063.55	0.00
Total return (BDT/ha)	1048147.16±26061.65a	1033624.66±16254.46a	1016804.65±3809.96a	0.77	0.50
Net profit (BDT/ha)	244412.10±26749.05b	278310.36±15805.77b	343624.38±3251.81a	7.81	0.02
BCR	0.30±0.03b	0.37±0.02b	0.51±0.00a	21.27	0.00

Figures bearing common letter(s) in a rowdo not differ significantly (p>0.05)

Table 73. Concentration of pathogenic bacteria (MPN/g) in carp fattening ponds of Paba upazila, Rajshahi during study period (July-December, 2020)

Treatment / Bacteria	T_1	T_2	T_3	F value	P value
Soil					
Total coliform	79.50±22.19[a]	70.16±13.54[a]	60.60±10.43[a]	0.34	0.72
Total faecal	86.50±17.29[a]	84.83±17.94[a]	72.90±24.36[a]	0.13	0.87
Water					
Total coliform	79.33±22.33[a]	80.66±24.68[a]	73.16±4.66[a]	0.04	0.95
Total faecal	37.83±13.58[a]	42.80±11.47[a]	35.00±5.40[a]	0.13	0.87
Fish flesh	Not detected				

Figures in a row bearing common letters as superscript do not differ significantly (p>0.05).

Table 74. Concentration of pathogenic bacteria (MPN/g) in carp fattening ponds of Tanore upazila, Rajshahi during study period (July-December, 2019)

Treatment / Bacteria	T_1	T_2	T_3	F value	P value
Soil					
Total coliform	63.33±8.66[a]	59.33±8.95[a]	44.66±5.23[a]	1.58	0.28
Total fecal	31.33±6.17[a]	30.66±5.69[a]	29.33±4.91[a]	0.03	0.96
Water					
Total coliform	11.50±1.75[a]	14.66±2.02[a]	10.16±0.44[a]	2.16	0.19
Total fecal	9.33±1.01[a]	11.00±2.02[a]	9.23±2.64[a]	0.24	0.79
Fish flesh	Below detection limit				

Figures in a row bearing common letters as superscript do not differ significantly (p>0.05).

Table 75. Heavy metal concentration in pond water and fish feed under carp fattening system

Heavy metal	**Source**	
	Pond water (ppm)	Fish feed (ppm)
Lead (Pb)	0.0024±0.0002	0.0052±0.001
Cadmium (Cd)	0.021±0.002	0.017±0.001

Table 76. Mean water quality and survival rate of live fishes under different treatments of loading densities during live fish transportation (March to June, 2020)

Parameter		Treatment			F-value	P-value
		T_1 (80 kg fish/ton water)	T_2 (100 kg fish/ton water)	T_3 (120 kg fish/ton water)		
Temperature (^{0}C)	Start	29.80±0.08a	30.05±0.23a	29.97±0.17a	0.52	0.61
	End	29.71±0.11a	30.06±0.27a	29.95±0.08a	0.95	0.44
pH	Start	7.95±0.09a	7.89±0.08a	7.97±0.10a	0.24	0.79
	End	7.46±0.05a	7.33±0.02a	7.28±0.13a	1.21	0.36
DO (mg/l)	Start	7.21±0.05a	7.17±0.22a	7.19±0.10a	0.04	0.96
	End	6.60±0.12a	6.37±0.09ab	6.19±0.11b	3.47	0.01
NH_3-N (mg/l)	Start	0.02±0.01a	0.02±0.01a	0.02±0.00a	0.08	0.92
	End	0.02±0.00b	0.04±0.00a	0.04±0.01a	9.57	0.01
Survival rate (%)		97.41±0.84a	95.00±0.80ab	92.91±0.54b	9.16	0.01

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 77. Variation in taste, odor and texture in cooked fishes under different treatments

Parameter	Treatments		
	T_1 (inorganic fertilizer, feed, silver carp inclusion)	T_2 (inorganic & organic fertilizer, feed, silver carp inclusion)	T_3 (inorganic & organic fertilizer, feed, silver carp exclusion)
Taste	Meaty	Between sweet and meaty	Slightly fishy
Odour	Species specific/Fresh	Fresh	Slightly fishy
Texture	Firm and elastic	Elastic	Less firm

Table 78. Water quality under different treatments of SIS-carp farming in ponds under Paba upazila, Rajshahi during study period (July-December, 2020)

Water quality	Treatments			F-value	P-value
	T_1	T_2	T_3		
Temperature (°C)	31.09±0.06a	30.95±0.12a	30.92±0.05a	1.06	0.40
DO (mg/l)	5.76±0.08a	5.70±0.08a	5.80±0.17a	0.17	0.84
pH	7.19±0.06a	7.15±0.01a	7.22±0.02a	0.32	0.73
Alkalinity (mg/l)	114.83±1.94a	115.50±5.15a	114.05±3.06a	0.40	0.96
Transparency (cm)	25.33±0.38a	25.55±0.30a	26.27±0.29a	2.21	0.19
NH3-N (mg/l)	0.05±0.01a	0.04±0.00b	0.04±0.00b	5.00	0.04
TDS (mg/l)	636.33±3.16a	627.72±9.60a	630.77±13.14a	0.20	0.81
CO2(mg/l)	1.96±0.02a	1.99±0.04a	1.78±0.12a	2.02	0.21

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 79. Fish growth under different treatments of SIS-carp farming in ponds under Paba upazila, Rajshahi during study period (July-December, 2020)

Species	Treatment	Initial weight (g)	Final weight (g)	Weight gain (g/6months)	SGR (%, bwd^{-1})	Survival rate (%)
C.batrachus	T_1	2.40±0.30a	133.46±2.40a	131.06±2.66a	2.24±0.07a	82.03±1.74a
	T_2	2.36±0.33a	127.43±4.29b	125.06±4.05b	2.22±0.06a	81.60±1.67a
	T_3	2.38±0.30a	113.96±3.08b	111.58±2.78b	2.15±0.05a	82.25±0.88a
F value		0.00	8.84	9.54	0.46	0.05
P value		0.99	0.01	0.01	0.65	0.95
G. catla	T_1	216.33±3.17a	1009.33±53.24a	793.00±52.82a	0.85±0.03a	77.69±3.09a
	T_2	224.33±3.17a	1020.00±12.22a	795.66±13.04a	0.84±0.01a	77.39±2.52a
	T_3	221.66±4.80a	990.33±45.72a	768.66±50.53a	0.83±0.03a	77.26±2.47a
F value		1.14	0.13	0.12	0.17	0.00
P value		0.37	0.87	0.88	0.84	0.99
H. molitrix	T_1	236.00±2.51a	1375.00±22.51a	1139.00±20.03a	0.97±0.00a	82.72±4.61a
	T_2	230.33±1.85a	1324.33±34.37a	1094.00±33.56a	0.97±0.01a	81.37±3.59a
	T_3	227.33±6.69a	1314.33±46.69a	1087.00±40.07a	0.97±0.00a	82.18±3.78a
F value		1.06	0.82	0.76	0.21	0.03
P value		0.40	0.48	0.50	0.81	0.79
L. rohita	T_1	108.66±2.40a	747.00±45.52a	638.33±46.81a	1.06±0.04a	74.35±3.17a
	T_2	113.33±2.84a	741.66±29.32a	628.33±29.44a	1.04±0.02a	75.03±3.69a
	T_3	112.00±4.04a	735.66±70.01a	623.66±65.98a	1.04±0.03a	74.22±2.20a
F value		0.57	0.10	0.02	0.02	0.02
P value		0.59	0.98	0.97	0.81	0.98

Figures bearing common letter(s) in a column do not differ significantly (p>0.05)

Table 80. Fish yield (kg/ha/6 months) under different treatments of SIS-carp farming in ponds under Paba upazila, Rajshahi during study period (July-December, 2020)

Species	**Treatments**			**F-value**	**P-value**
	T_1	T_2	T_3		
C.batrachus	7720.21±250.97a	7411.00±361.94ab	6626.00±162.88b	4.32	0.04
H. molitrix	212.69±22.74a	202.39±14.89a	206.42±16.78a	0.08	0.92
G. catla	300.17±33.64a	282.74±13.11a	276.00±9.68a	0.33	0.72
L. rohita	111.08±5..37a	105.30±4.04a	107.94±5.03a	0.35	0.71
All species	8344.17±237.59a	8001.34±370.60ab	7216.37±142.83b	4.68	0.03

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 81. Economics of SIS-carp farming in pond (1 ha) under Paba upazila, Rajshahi for six months culture period (July-December, 2020)

Items	Treatments			F-value	P-value
	T_1	T_2	T_3		
Variable cost(BDT/ha)					
Seed	279975.32±194.32a	280439.68±295.84a	280183.62±117.37a	1.16	0.37
Feed	970581.33±14396.85a	746997.00±32277.88b	593737.00 ±6602.65c	92.27	0.00
Fixed cost (BDT/ha)					
Lime	15000.00±0.00	15000.00±0.00	15000.00±0.00	-	-
Fertilizer	6470.00±0.00	6470.00±0.00	6470.00±0.00	-	-
Labour	25000.00±0.00	25000.00±0.00	25000.00±0.00	-	-
Harvest	21500.00±0.00	21500.00±0.00	21500.00±0.00	-	-
Total cost (BDT/ha)	1318526.65±14346.59a	1095406.68±30032.73b	941890.62±6698.25c	93.35	0.00
Total return (BDT/ha)	2957982.41±86776.48a	2785098.05±144769.70ab	2461152.18±85222.98b	5.33	0.00
Net benefit (BDT/ha)	1639455.75±82624.22a	1689691.37±16924.10a	1519261.55±79631.85a	0.55	0.60
BCR	1.24±0.06b	1.55±0.19ab	1.61±0.07a	2.43	0.02

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 82. Water quality under different treatments of SIS-carp farming in ponds under Tanore upazila, Rajshahi during study period (July-December, 2020)

Water quality	Treatments			F-value	P-value
	T_1	T_2	T_3		
Temperature (°C)	30.78±0.10a	30.90±0.11a	30.83±0.01a	0.46	0.65
DO (mg/l)	5.41±0.19a	5.40±0.16a	5.62±0.05a	0.69	0.53
pH	6.84±0.07a	6.87±0.04a	6.84±0.15a	0.03	0.96
Alkalinity (mg/l)	94.72±2.58a	94.33±5.34a	93.50±1.98a	0.03	0.97
Transparency (cm)	24.94±0.05a	25.16±0.41a	25.61±0.54a	0.72	0.52
NH3-N (mg/l)	0.05±0.00a	0.05±0.00a	0.04±0.00b	13.40	0.01
TDS (mg/l)	257.83±5.08a	264.00±3.37a	255.72±1.81a	1.36	0.32
CO_2(mg/l)	2.03±0.06a	1.96±0.06a	1.84±0.08a	1.80	0.24

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 83. Fish growth under different treatments of SIS-carp farming in ponds under Tanore upazila, Rajshahi during study period (July-December, 2020)

Species	Treatment	Initial weight (g)	Final weight (g)	Weight gain (g/6 months)	SGR (%, bwd^{-1})	Survival rate (%)
C. batrachus	T_1	2.45±0.30a	130.06±2.05a	127.61±1.77a	2.21±0.05a	81.94±1.70a
	T_2	2.51±0.27a	125.71±4.25a	123.19±4.00a	2.17±0.04a	81.48±1.71a
	T_3	2.41±0.29a	112.14±1.49b	109.73±1.20b	2.14±0.05a	81.86±1.18a
F value		0.03	10.67	12.61	0.49	0.02
P value		0.96	0.01	0.00	0.63	0.97
G.catla	T_1	218.00±4.50a	1037.00±55.47a	819.00±51.17a	0.86±0.01a	79.35±3.00a
	T_2	223.00±5.50a	1015.66±15.05a	792.66±16.45a	0.84±0.01a	78.27±1.96a
	T_3	221.66±8.83a	995.33±42.33a	773.66±51.17a	0.83±0.04a	78.61±2.47a
F value		0.15	0.25	0.28	0.28	0.05

Species	Treatment	Initial weight (g)	Final weight (g)	Weight gain (g/6 months)	SGR (%, bwd^{-1})	Survival rate (%)
P value		0.85	0.78	0.76	0.76	0.95
H. molitrix	T_1	237.00±2.51a	1345.00±42.50a	1108.00±41.10a	0.96±0.01a	81.37±4.25a
	T_2	234.33±4.66a	1311.00±29.10a	1076.66±30.33a	0.95±0.02a	80.29±3.40a
	T_3	227.66±8.87a	1298.67±48.01a	1071.00±39.52a	0.96±0.00a	81.78±3.59a
F value		0.64	0.34	0.28	0.16	0.04
P value		0.55	0.71	0.76	0.85	0.96
L. rohita	T_1	109.33±4.70a	745.66±28.08a	636.33±23.67a	1.06±0.01a	75.16±3.77a
	T_2	114.66±3.17a	733.00±21.07a	618.33±20.73a	1.03±0.02a	73.95±3.05a
	T_3	113.66±8.41a	726.33±47.42a	612.66±40.33a	1.03±0.02a	75.97±1.32a
F value		0.23	0.08	0.17	1.51	0.12
P value		0.79	0.92	0.84	0.29	0.88

Figures bearing common letter(s) in a column do not differ significantly (p>0.05)

Table 84. Fish yield (kg/ha/6 months) under different treatments of SIS-carp farming in ponds under Tanore upazila, Rajshahi during study period (July-December, 2020)

Species	Treatments			F-value	P-value
	T_1	T_2	T_3		
C.batrachus	7937.16±269.21a	7539.49±388.75ab	6773.69±235.43a	3.76	0.04
H. molitrix	223.17±19.86a	209.69±17.00a	211.10±18.35a	0.11	0.89
G. catla	281.50±34.64a	279.37±15.55a	267.44±10.31a	0.16	0.85
L. rohita	110.94±13.73a	108.95±1.92a	106.60±9.24a	0.05	0.95
All species	8552.79±224.99a	8137.51±403.68ab	7358.85±211.86b	4.26	0.03

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

Table 85. Economics of SIS-carp farming in pond (1 ha) under Tanore upazila, Rajshahi for six months culture period (July-December, 2020)

Items	Treatments			F-value	P-value
	T_1	T_2	T_3		
Variable cost(BDT/ha)					
Seed	280110.35±345.45a	280500.61±243.93a	280246.61±320.37a	0.41	0.67
Feed	960498.00±13440.80a	738590.33±30680.90b	586300.33±4491.89c	93.01	0.00
Fixed cost(BDT/ha)					
Lime	16000.00±0.00	16000.00±0.00	16000.00±0.00	-	-
Fertilizer	5900.00±0.00	5900.00±0.00	5900.00±0.00	-	-
Labour	24500.00±0.00	24500.00±0.00	24500.00±0.00	-	-
Harvest	20500.00±0.00	20500.00±0.00	20500.00±0.00	-	-
Total cost (BDT/ha)	1307508.35±13148.70a	1085990.94±30495.50b	933446.94±4810.89c	94.25	0.00
Total return (BDT/ha)	2884962.73±93422.25a	2743649.20±13486.54ab	2412791.72±60156.32b	5.77	0.04
Net benefit (BDT/ha)	1577454.34±10199.22a	1657658.26±16503.61a	1479344.78±55446.94a	0.59	0.58
BCR	1.21±0.08b	1.54±0.19ab	1.58±0.05a	2.57	0.03

Figures bearing common letter(s) in a row do not differ significantly (p>0.05)

11.7. Effects of supplementary feeds on the production and economics of carp fattening in ponds in coastal area (by PSTU 2020)

1.a.Water Quality Parameters

The average value of water quality parameters viz., water Temperature (^{0}C), Dissolved Oxygen (mg/l), pH, Alkalinity (mg/l), Nitrite (mg/l), Ammonia (mg/l) were measured during the study period are shown in Table 86.

Table 86. Water quality parameters for carps in the experimental ponds (mean ± SD)

Parameters	Treatment		
	$Factory_{100\%}$	**$Factory_{70\%}$**	**Restricted**
Temperature (^{0}C)	29.31±1.26	29.37±1.10	29.32±1.16
DO (mg/l)	5.54±1.71	5.17±2.16	5.84±1.53
pH	7.56±0.33	7.56±0.41	7.59±0.25
CO_2 (mg/l)	12.73±3.10	11.33±3.70	11.47±4.21
Alkalinity (mg/l)	176.60±60.41^{ab}	210.33±68.01^{a}	141.73±37.78^{b}
Nitrite (mg/l)	0.03±0.04	0.01±0.01	0.04±0.10
Ammonia (mg/l)	0.08±0.10	0.10±0.12	0.04±0.05

Water quality parameters were not significantly different among the treatments except alkalinity. All water quality parameters were found within the suitable range for carp fish culture.

1.b. Production performance of carps

Production performance of carp fishes in term of weight (g) gain under different treatments for a period of 210 days is presented in the Table 87.

Table 87. Growth performances of carps observed in different treatments

Parameters	Treatment		
	$Factory_{100\%}$	**$Factory_{70\%}$**	**Restricted**
Initial wt (g)	356.40±28.75	339.80±00	339.80±00
Final wt (g)	1012.80±230.08	1078.87±58.65	1015.33±48.91
SGR (%/day)	0.57±0.10	0.64±0.03	0.61±0.26
Survival rate (%)	98.29±0.46	97.79±0.81	97.89±0.27
Production (kg/ha/210d)	3709.92±587.80	3492.42±62.37	3161.41±222.55

The highest mean final weight 1078.87 g carp was found in those ponds under the $Factory_{70\%}$ whereas the lowest mean final weight 1012.80 g carp was found in those ponds under the $Factory_{100\%}$. The SGR of carp in different treatment ranged 0.57 to 0.64. The significantly highest SGR values (0.64) for carp was found in $Factory_{70\%}$ whereas lowest SGR values (0.57) was found in $Factory_{100\%}$.The highest production 3709.92 kg/ha/210d was found in those ponds under Factory$_{100\%}$ whereas the lowest production 3161.41 kg/ha/210d was found in those ponds under Restricted.

11.8. GAP aspects

11.8.1. Determination of heavy metals

Table 88. Mean metal concentrations (±SD, µg/g dry wt) in muscle, soil and water samples from carp fattening ponds

Metal	Sample	Factory$_{100}$	Factory$_{70}$	Restricted
Pb	Muscle	ND	ND	ND
	Soil	3.60±0.82	3.30±3.05	4.10±0.96
	Water	0.033±0.006^{a}	0.013±0.006^{b}	0.03±0.010^{a}
Cd	Muscle	0.003±0.006	0.003±0.006	0.007±0.006
	Soil	0.017±0.011	0.02±0.01	0.01±0.00
	Water	0.01±0.00	0.013±0.006	0.01±0.00

ND=Below Detection limit

The Pb concentration in the muscle was below detection level (ND) in all treatments. Concentration of Pb in the soil varied from 3.30 to 4.10 µg/l among the different treatments. The Pb concentration in the water was significantly difference among the different treatments. The highest Pb concentration in the water was in the treatment Factory$_{100}$.

The Cd concentration in the muscle varied 0.003 µg/l to 0.007 µg/l among the different treatments. Concentration of Pb in the soil varied from 0.01 to 0.02 µg/l among the different treatments (Table 88). The highest Pb concentration in the water was in the treatment Factory$_{70}$. Comparatively lower heavy metals concentration was observed in the muscle in all treatments and higher heavy metals concentration was observed in the soil in all treatments.

Muscle accumulated the low concentrations of Pb (ND) and Cd (0.003-0.007), dry wt, which agreed with the previous studies in the other regions of the world (Allinson *et a*l., 2002; Taweel *et al*., 2013; Dhanakumar *et al*., 2015).

11.8.2. Pathogenic microbial load

Table 89. Bacterial load in soil, water and fish muscle is observed in carp ponds

Parameters	Treatment		
	Factory$_{100}$	Factory$_{70}$	Restricted
Soil (cfu/g)	6.02 x 10^{7b}	7.03 x 10^{7a}	5.18 x 10^{7b}
Water (cfu/ml)	2.48 x 10^{4}	2.12 x 10^{4}	1.99x10^{4}
Fish muscle (cfu/g)	4.26 x 10^{6b}	5.03 x 10^{6a}	3.79 x 10^{6b}

Total bacterial load in water determine as aerobic plate count was 1.99x10^{4} cfu/ml to 2.48x10^{4} cfu/ml which was lower than the findings of Shankar *et al.* (2009) and Banu *et al.* (2001) who determined total bacterial load in water 1.43-0.18x10^6cfu/ml and 1.39x 10^5 to 3.11x 10^7cfu/ml of water, respectively(Table 89).

The higher bacterial load was in soil in all treatments followed by fish muscle and water in all treatments.

11.8.3. Economic analysis

The economic analysis of the experiment is shown in Table 90.

Table 90. Benefit cost ratio (BCR) of different treatments of carp fattening in ponds under coastal area

Benefit-cost	$Factory_{100\%}$	$Factory_{70\%}$	Restricted
Total variable costs (Taka)	734686	694350	615235
Total income (Taka)	927480	873105	790450
Net benefit return	192794	178755	175215
Benefit cost Ratio (BCR)	1.26	1.26	1.28

The total cost (Tk. 734686) and the total income (Tk. 927480) was highest in treatment $Factory_{100\%}$. The highest net benefit return was also found in treatment $Factory_{100\%}$ (Tk. 192794). The highest BCR was found in the treatment restricted feeding (1.28) which might be associated with the lowest variable cost in this treatment (Table 90).

11.9. Effects of supplementary feeds on the production and economics SIS fish (Magur, *Clarias batrachus*) farming in homestead ponds under coastal area

1.a. Water Quality Parameters

Table 91. Water quality parameters for Magur in the experimental ponds (mean ± SD)

Parameters	Treatment		
	$Factory_{100\%}$	$Factory_{70\%}$	Restricted
Temperature (^{0}C)	29.06±1.01	29.56±1.10	29.56±1.15
DO (mg/l)	3.89±1.18^a	3.94±0.73^a	5.61±1.98^b
pH	7.28±0.46	7.28±0.46	7.50±0.51
Alkalinity (mg/l)	132.20±44.41^a	148.67±45.42^a	188.93±62.16^b
Nitrite (mg/l)	0.20±0.46	0.06±0.07	0.14±0.16
Ammonia (mg/l)	0.12±0.15	0.14±0.13	0.08±0.11

The mean values of DO and alkalinity was significantly higher in the treatment restricted feeding than the other treatments. The mean value of DO was somewhat lower in the treatments $Factory_{100\%}$ and $Factory_{70\%}$than the suitable range for the fish culture (Banerjea, 1967) which might be decomposed of unused feed (Table 91). The mean values of ammonia were 0.12 mg/l, 0.14 mg/l and 0.08 mg/l in the treatments $Factory_{100\%}$, $Factory_{70\%}$and restricted feeding, respectively which were the suitable range for the fish culture by Bhatnagar and Singh (2010) and the value is <0.2 mg/l.

1.b. Production performance of Magur

Production performance of Magur fishes in term of weight (g) gain under different treatments for a period of 210 days is presented in the Table 92.

Table 92. Growth performances of Magur observed in different treatments

Parameters	Treatment		
	Factory$_{100\%}$	**Factory$_{70\%}$**	**Restricted**
Initial weight (g)	1.42±0.00	1.42±0.00	1.42±0.00
Final weight (g)	109.67±6.81^{a}	102.67±5.03^{ab}	95.33±7.37^{b}
SGR (%/day)	2.41±0.04^{a}	2.38±0.03^{ab}	2.34±0.04^{b}
Survival rate (%)	72.61±3.70	68.71±1.75	70.27±1.83
Production (kg/ha/270 d)	5890.24±193.34^{a}	5225.50±246.63^{ab}	4969.88±496.93^{b}

The mean final weight of Magur was significantly highest in the treatment Factor$_{100\%}$(109.67 g) and the lowest of the same was found in those ponds under the treatment restricted (95.33 g). The SGR of Magur in different treatment ranged 2.34 to 2.41. The significantly highest SGR values (2.41) for Magur was found in Factory$_{100\%}$ whereas lowest SGR values (2.34) was found in restricted feeding. The highest production 5890.24 kg/ha/210d was found in those ponds under Factory$_{100\%}$whereas the lowest production 4969.88 kg/ha/210d was found in those ponds under Restricted which might be associated with the final weight and SGR.

1.c. Economic analysis

The economic analysis of the experiment is shown in Table 93.

Table 93. Benefit cost ratio (BCR) of different treatments of Magur in ponds under coastal area

Benefit-cost	Factory$_{100\%}$	Factory$_{70\%}$	Restricted
Total variable costs (Taka)	1187414	989921	937704
Total income (Taka)	1531462	1358630	1292169
Net benefit return	344048	368709	354465
Benefit cost Ratio (BCR)	1.29	1.37	1.38

The total cost (Tk. 1187414) and the total income (Tk. 1531462) was highest in treatment Factory$_{100\%}$. The highest net benefit return was found in treatment Factory$_{70\%}$ (Tk. 368709). However, the highest BCR was found in the treatment restricted feeding (1.38) which might be associated with the lowest variable cost in this treatment.

12. Research highlight

12.1. Component-1 (RU)

Title of the sub-project : ***Improvement of existing fattening technology of carp and high valued small indigenous species (SIS) through good aquaculture practices (GAP) in different agro-ecosystems***

Research highlight: 01

Background: Use of larger size and overwintered seeds in carp fattening is potential for fish production within shorter period in ponds under drought prone area. Lack of appropriate guidelines for low cost fish production are the major constraints for carp fattening. Off flavor in fishes is also adversely affecting the sustainability of carp fattening. Therefore, efforts were necessary for the development of sustainable carp fattening in ponds under drought prone area of Bangladesh.

Objective 1: To identify good practices and develop sustainable carp fattening technology.

Methodology: Base line survey of 36 farmers and several FGDs were conducted. Three different treatments of species combinations (T_1: surface-30%, column-40% and bottom feeder-30%; T_2: surface-40%, column-30% and bottom feeder-30%; and T_3: surface-35%, column-35% and bottom feeder-30%), stocking densities (fishes/ha) (T_1: 2470; T_2: 3705; and T_3: 4940) and feed (T_1: regular feeding of 100% factory feed; T_2: regular feeding of 70% factory feed; and T_3: restricted feeding once per week of 70% factory feed) were tested in 3 successive years. Organoleptic study was also done to determine the causes of taste variation in carps.

Key findings: Surface feeder (40%) dominant carps with a density of 2470 fishes/ha was profitable under restricted feeding regime of factory and home-made feed. Natural taste in fish with safe level of heavy metal and pathogenic bacterial load was noted in ponds under GAP management.

Key words: Carp, Fattening, GAP, Pond, Drought

Research highlight: 02

Background: Farming of nutrient rich and short cycle small indigenous species (SIS) of fish by the distressed women is considered potential technique for homestead ponds under drought prone area. Lack of guidelines in selecting appropriate species, density and feed are major constraints for the promotion of low cost SIS fish farming. Therefore, efforts were necessary for the development of appropriate SIS fish farming in homestead ponds under drought prone area of Bangladesh.

Objective 2: To promote high valued SIS fish farming by the distressed women in homestead ponds.

Methodology: Base line survey of 36 farmers and several FGDs were conducted. Three treatments of species (T_1: Shing, *H. fossilis*; T_2: Magur, *C. batrachus*; and T_3: Gulsha, *M. cavasius*), stocking densities (fishes/ha) (T_1: 37,050; T_2: 74,100; and T_3: 111,150) and feed (T_1: regular feeding of 100% factory feed; T_2: regular feeding of 70% factory feed; and T_3: restricted feeding once per week of 70% factory feed) were tested in 3 successive years.

Key findings: Magur *C. batrachus* with a density of 74,100 fishes/ha was found profitable in homestead ponds under restricted feeding management of factory and home-made feed.

Key words: SIS, Farming, Drought, Homestead pond

Research highlight: 03

Background: There is a greater demand of larger size fish while finding it at live condition in terms of safety aspects to the consumers. And thus carp fattening is gaining popularity in Rajshahi area to produce and supply larger size fishes. Larger size live fishes (carps) are transported to Dhaka and other parts of Bangladesh through more than hundred trucks during peak season. Usually fishes are loaded with high densities and are often prone to stress due to poor water quality while transportation in truck especially at distant places. Therefore, efforts were necessary for the development of appropriate technology for live fish transportation.

Objective 3: To develop viable technology for live fish transportation.

Methodology: Water quality and survival rate of fishes were evaluated under three different treatments of loading densities (kg fish per ton of water) in truck (T_1: 80; T_2: 100; and T_3: 120) for live fish transportation from Rajshahi to Dhaka.

Key findings: Loading density of 80 kg fish/ton water reduced ammonia level and increased survival rate.

Key words: Water quality, Survival rate, Transportation, Live fish

Research highlight: 04

Background: Carp fattening technique has tremendous potentials for producing and marketing larger size fishes within shorter production period involving different actors engaged in farming, marketing and overall value chain. Appropriate management practices are considered important for producing safe fish, removing off flavor and thereby developing sustainable technology. On the other hand, as a short cycle profitable technology, culture of SIS fishes have also potentials for the development of appropriate technology by the distressed women especially in homestead ponds under drought prone areas in Bangladesh. Appropriate guidelines are required for effective utilization of these homestead ponds. Therefore, efforts were necessary to increase the capacity of farmers, entrepreneurs and market players.

Objective 4: To increase capacity of farmers, entrepreneurs and market players.

Methodology: Module based group discussion was conducted.

Key findings: Increased capacity of the farmers, entrepreneurs and market players in terms of increased production and income; reduced off flavor in fishes; and increased survival rate in live fish transportation.

Key words: GAP, Group discussion, Module, Pond management

Research highlight: 05

Background: Fattening of carps and farming of nutrient rich SIS fishes are potentials for aquaculture promotion in ponds under drought prone areas of Bangladesh. Availability of the appropriate information and integration of the suitable extension approach are considered important for sustainability of these potential techniques. Developing the information extension communication (IEC) materials and sharing the findings through workshop or conference are proven techniques for the effective dissemination of the research findings. Therefore, efforts were taken to disseminate findings and recommendations obtained from the research on carp fattening and SIS fish farming in ponds under drought prone area.

Objective 5: To disseminate findings and recommendations.

Methodology: Efforts were taken through producing findings based printed materials; and conducting and participating findings sharing workshop.

Key findings: Four scientific articles and two leaflets were developed; findings also presented in workshop at home and abroad.

Key words: Findings, Dissemination, Printed material, Workshop

12.2. Component-2 (PSTU)

Title of the sub-project : ***Improvement of existing fattening technology of carp and high valued small indigenous species (SIS) through good aquaculture practices (GAP) in different agro-ecosystems***

Research highlight: 01

Background: Carp polyculture in pond is the most popular technique among the majority of fish farmers and it contributes 52.06% of the total pond production in Bangladesh (DoF, 2019). Despite the popularity of current polyculture technique, carp fattening technique has added a new dimension in commercial fish farming to produce and market larger sized carps using larger stocking size of fishes in ponds compared to that of smaller stocking size practiced traditionally. Since the concept of carp polyculture is found to utilize the maximum species of three different niches in pond ecosystem, salinity in southwestern Bangladesh are considered to be major problems for pond polyculture to maximize production through utilization of the niche based species. Lack of guidelines in selecting appropriate combination of species is hindering fish production.

Objective: To determine a suitable species combination for carp fattening technology in ponds under Kalapara upazila of Patuakhali district.

Methodology: Three (3) categories of carp species (surface feeder: *Gibelion catla*, *Hypophthalmicthys molitrix*; column feeder*: Labeo rohita*; bottom feeder: *Cirrhinus cirrhosus* and *Cyprinus carpio*) combinations were used for the experiment. The experiment was consisted of 3 treatments, each with 3 replications, namely SC-$S_{30}C_{40}B_{30}$, SC-$S_{40}C_{30}B_{30}$ and SC-$S_{35}C_{35}B_{30}$. After pond preparation, the carp fishes were collected from Jashore and stocked in all experimental ponds by maintaining standard procedure. The stocking density was 10 individual/decimal. Artificial feed with 25% protein were fed for carp fishes**.** The feed was supplied 3% of fish body weight during the experiment. Half of the ration was supplied at 9.00 am and remains half was supplied at 3.00 pm. The physico-chemical parameters of water in ponds viz. water temperature (°C), pH, dissolved oxygen (mg/l), alkalinity (mg/l), nitrate (mg/l), ammonia-nitrogen (mg/l), CO_2 (mg/l), TDS (mg/l) and plankton concentration were monitored monthly as per standard methods. An economic analysis was performed to estimate the net benefit and benefit cost ratio (BCR) from different treatments.

Key findings: Water quality parameters were not significantly different among the treatments. All water quality parameters were found within the suitable range for carp fish culture. The SGR of carp in different treatment ranged between 0.88 and 0.93. The significantly highest SGR values (0.93) for carp was found in SC-$S_{35}C_{35}B_{30}$ whereas lowest SGR values (0.88) was found in SC-$S_{30}C_{40}B_{30}$. Production of carp in treatments SC-$S_{30}C_{40}B_{30}$, SC-$S_{40}C_{30}B_{30}$ and SC-$S_{35}C_{35}B_{30}$ were found 3640.92±187.82 kg/ha, 3656.47±16.84 kg/ha and 4078.52±148.32 kg/ha, respectively with higher production recorded in SC-$S_{35}C_{35}B_{30}$ which might be associated with higher SGR of carp obtained in this treatment. BCR was obtained 1.54, 1.48 and 1.75 in SC-$S_{30}C_{40}B_{30}$, SC-$S_{40}C_{30}B_{30}$ and SC-$S_{35}C_{35}B_{30}$, respectively. BCR was higher in SC-$S_{35}C_{35}B_{30}$ because of the highest yield was obtained in SC-$S_{35}C_{35}B_{30}$ than the other treatments.

Key words: Carp fattening, Species combination, Water quality parameters, Economic analysis.

Research highlight: 02

Background: Carp fattening is a modern scientific technique in aquaculture. This practice is increasing day by day around all over the world. At present this culture system is starting in Bangladesh. Generally, in this technique big size fish is stored in the pond. Natural and supplementary feed is used for the fish. In carp fattening technique, the production per Bigha is about 1000 to 1200 kg. In our country, the farmer always use small size fish causes the production is low. The practice is usually in short time. The stocking density is very crucial for carp fattening. Usually low stocking density is used for more production. With the importance of carp fattening idea, the present study was conducted to determine the suitable stocking density for carp fattening technology in ponds of Patuakhali district, Bangladesh.

Objective: To determine the optimum stocking density of carp fishesfor carp fattening technology.

Methodology: Based on the suitable species combination such as surface feeder-35%, column feeder -35% and bottom feeder-30% from 1st year experiment, 3 treatments were used for determining suitable stocking densities, each with 3 replications, namely SD-10, SD-15 and SD-20. Carp fishes such as Silver carp, Catla, Rui, Mrigal and Common carp were stocked in the experimental ponds and the average initial weight was 426 g. Artificial feed with 25% protein were fed for carp fishes**.** The feed was supplied 3% of fish body weight at the beginning of the experiment. Water temperature (°C), dissolved oxygen (mg/l), pH and Total Dissolved Solids (TDS) (mg/l) were determined monthly by HQ 40D Multimeter. Free carbon dioxide (mg/l), ammonia-nitrogen (mg/l), nitrate- nitrogen (mg/l) and alkalinity (mg/l) were measured monthly by HACH kit (FF2, USA). An economic analysis was performed to estimate the net benefit and benefit cost ratio (BCR) from different treatments.

Key findings: Water quality parameters were not significantly different among the treatments except TDS. All water quality parameters were found within the suitable range for carp fish culture. SGR of carps were 0.56±0.13 %/day, 0.47±0.09 %/day and 0.34±0.06 %/day in SD-10, SD-15 and SD-20, respectively. SGR of carp was significantly higher in SD-10 compared to other treatments, where carp was stocked at the rate of 10 individual/decimal. Production of carp in treatments SD-10, SD-15 and SD-20 were found 2941.92±589.44 kg/ha, 3875.63±684.63 kg/ha and 2739.76±80.95kg/ha, respectively with higher production recorded in SD-15 which might be associated with higher survival rate of carp obtained in this treatment. BCR was obtained 1.41, 1.26 and 0.68 in SD-10, SD-15 and SD-20, respectively. BCR was higher in SD-10 because of the lowest variable cost in SD-10 than the other treatments.

Key words: Carp fattening, Stocking density, Water quality parameters, Economic analysis.

Research highlight: 03

Background: The use of supplementary feed has become inevitable for the success of fish culture. In order to get maximum yield of fish from confined water, it is essential to use supplementary feed along with chemical fertilizer and organic manure. Supplementary feeding is known to increase the carrying capacity of culture systems and can enhance fish production by many folds. It also offers the best means of fish production within the shortest possible time in the ponds. Application of manures and other fertilizers, as well as the excess use of feeds may reduce the quality of pond water. In the case of pond culture of carp, the combined use of natural fish food and supplementary or/and balanced feeds is a technique which promotes both a good pond environment and improved fish nutrition.

Objective: To determine the effects of supplementary feeds on the yield and economics of carp fattening in ponds under coastal area of Bangladesh.

Methodology: The experiment was conducted with 3 treatments and each with 3 replications. Three treatments were designated with**:**

$Factory_{100\%}$: regular feeding of 100% factory feed.
$Factory_{70\%}$: regular feeding of 70% factory feed and 30% home-made feed.

Restricted: restricted feeding (no feeding once per week) of 70% factory feed and 30% home-made feed. After pond preparation, the carp fishes were collected from local nursery and stocked in all experimental ponds by maintaining standard procedure. Based on the suitable stocking density from 2^{nd} year experiment, the carp fishes were stocked at the 10 individual/decimal. Home-made and factory-made feed with 25% protein were fed for carp fishes. Feed was adjusted fortnightly according to the total biomass of fish obtained from the sampling as part of monitoring fish growth. The feed was supplied 3% of fish body weight during the experiment. Half of the ration was supplied at 9.00 am and remains half was supplied at 3.00 pm. The physico-chemical parameters of water in ponds viz. water temperature (°C), pH, dissolved oxygen (mg/l), alkalinity (mg/l), nitrate (mg/l), ammonia-nitrogen (mg/l), CO_2 (mg/l), TDS (mg/l) and plankton concentration were monitored monthly as per standard methods. An economic analysis was performed to estimate the net benefit and benefit cost ratio (BCR) from different treatments.

Key findings: Water quality parameters were not significantly different among the treatments except alkalinity. All water quality parameters were found within the suitable range for carp fish culture. The SGR of carp in different treatment ranged 0.57 to 0.64. The significantly highest SGR values (0.64) for carp was found in $Factory_{70\%}$ whereas lowest SGR values (0.57) was found in $Factory_{100\%}$. The highest production 3709.92 kg/ha/210d was found in those ponds under $Factory_{100\%}$ whereas the lowest production 3161.41 kg/ha/210d was found in those ponds under Restricted. The highest BCR was found in the treatment restricted feeding (1.28) which might be associated with the lowest variable cost in this treatment.

Key words: Carp fattening, Supplementary feed, Water quality parameters, Economic analysis.

Research highlight: 4

Background: Small indigenous fish species (SIS) is denoted the species of fish which can grow to a maximum size of 25 cm or 9 inches in their mature or adult stage of lifecycle. About 260 indigenous freshwater fish species are available in Bangladesh of which 143 has been reported as SIS. These species have been considered as an excellent source of essential protein, macro and micro-nutrients, vitamins and minerals, which can play a significant role in the fulfillment of nutritional deficiency in human being. A large number of SIS are still existing in various water bodies including rivers, beels, khals, haors, baors etc of Bangladesh but their existence is at stake in almost every water bodies due to indiscriminate catching of SIS by numerous baleful fishing gears leading SIS to a high risk of extinction. Aquaculture of high valued small indigenous species (SIS) of fishes is also found potentials not only for food and nutrition supply and income generation but also for effective utilization of the water bodies especially by the poor women in the rural areas of south-western Bangladesh. The saline water in south-western Bangladesh are considered to be major problems for aquaculture. Such problems can be minimized through developing sustainable aquaculture of SIS fishes in homestead ponds by the poor women. Freshwater Magur, *Clarias batrachus* is highly delicious and fast-growing catfish in Bangladesh.

In earlier, a large number of native or local Magur fish was found available in natural sources. Now-a-days, the native or local Magur is not found available due to the man-made causes and indiscriminately fishing. In this regard, there is no alternative to culture in the pond for protecting this fish. It can survive easily in adverse environmental condition like shallow water depths, deficiency of oxygen level, polluted water or high-water temperature etc., therefore, there is ample opportunity to culture this fish in seasonal ponds or small size homestead ponds. Traditionally fish farmers cultured this fish both mono and polyculture systems. The potential expansion of Magur culture will provide high quality nutrition to lower-income families. It is necessary to need urgent steps for the sustainable culture and management strategy of highly nutritious and high market demand of magur fish through the participation of rural women in homestead ponds.

Objectives

- To determine suitable species of SIS (Shing, Magur, Gulsha) fishes for farming in homestead ponds under coastal area;
- To determine optimum stocking density of walking catfish (*C. batrachus*) in homestead ponds; and
- To determine effects of supplementary feeds on the production and economics of walking catfish (*C. batrachus*) in homestead ponds.

Methodology: Three experiments were carried out for SIS at Kalapara upazila under Patuakhali district: Species suitability for SIS fish farming; Stocking density optimization for SIS fish farming; and Suitability of supplementary feed in SIS fish farming. SIS fry were collected from Chanchal matshya hatchery at Bauphal in Patuakhali for 1st and 3rd trial and Jashore for 2nd trial and stocked in the experimental ponds. The SIS were fed commercial factory feed for 1st and 2nd trial and home-made supplementary feed were used with commercial factory feed for 3rd trial. Physical and chemical parameters of water were monitored monthly. The fish were collected from each experimental pond manually after draining out the water from the ponds. The collected fish were then counted and the number was recorded separately pond wise. An economic analysis was performed to estimate the net benefit and benefit cost ratio (BCR) from different treatments.

Key findings: In 1st trial of SIS, among three SIS species, the highest production and BCR was in SP-Magur (3289.52 ± 372.44 kg/ha/270 days) and (2.13), respectively. In 2nd trial of SIS, the highest production recorded in the treatment SD-300 (6173.63±418.36). The highest BCR was also obtained in the treatment SD-300 (1.53). In 3rd trial of SIS, the highest production 5890.24 kg/ha/210d was found in those ponds under Factory$_{100\%}$ whereas the lowest production 4969.88 kg/ha/210d was found in those ponds under restricted which might be associated with the final weight and SGR and the highest BCR was found in the treatment restricted feeding (1.38) which might be associated with the lowest variable cost in this treatment. All the water quality parameters were found within the suitable range for SIS fish culture in all trials.

Key words: Small Indigenous Species, Benefit Cost Ratio, Stocking density, Supplementary feeding.

Research highlight: 05

Background: Fisheries sector is considered one of the potential sub-sectors of agriculture. This sector contributes significantly to improving nutrition status, generating rural employment opportunities, reducing rural poverty and inequality; and earning foreign exchange for Bangladesh. The livelihood of about 6.7 million people of the country, directly and indirectly, depend on the fisheries sector. Nevertheless, the socioeconomic condition of fishing community shows a dismal picture. Researchers find that the fish farmers in Bangladesh have low level of education, lack of physical and financial assets and lack of skills.

Due to lack of adequate knowledge and skills of the fish farmers towards carp fattening and SIS fish farming they are not able to maximize their productivity. Because fisheries technology is continuously changing, many skills are needed for use of these techniques by the fish farmers in increasing production. For this reason, it is necessary to arrange timely training programmers to acquire necessary knowledge and skills in different aspects of carp fattening and SIS fish farming.

Objective: To increase capacity of farmers, entrepreneurs and market players.

Methodology: Training on carp fattening technology and culture of Magur was conducted in the study area. Farmers group discussion was also (with focus on pond management, GAP and problem solving aspects) conducted in the research area. Experimental findings were shared through developing leaflets and conducting technology based field day. Fish farmers were visited Rajshahi areas for gathering knowledge on carp fattening. Different experts from BARC and RU visited sub-projects areas.

Key findings

- Capacity of fish farmers on carp fattening technology and SIS farming were enhanced through conducting training and group discussion.
- Existing knowledge of fish farmers were increased through visiting Rajshahi areas where carp fattening is well practiced.
- Different experts from BARC and RU visited sub-projects areas and farmers were benefited through sharing experiences with them.

Key words: Capacity, Training, Group Discussion

B. Implementation Status

1. Procurement

Coordination component (BARC)

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
a. Office equipment Procurement of Computer and Accessories Desktop computer-2, Laptop-1, Laser Printer-1, UPS-2, Scanner-1,	02 01 01 02 01	225000/-	Computer-2, Laptop-1, Laser Printer-1, UPS-2, Scanner-1,	225000/-	!00% achieved
(b) Lab &field equipment					
(c) Other capital items					

Component -1 (RU)

Description of equipment	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk.)	Physical (No.)	Financial (Tk.)	
(a) Office equipment	03	709500.00	03	704700.00	
(b) Lab & field equipment	04	1083000.00	04	1368600.00	
(c) Other capital items					

Component -2 (PSTU)

Description of equipment and capital items	PP Target		Achievement		Remarks
	Physical (No.)	Financial (Tk)	Physical (No.)	Financial (Tk)	
(a) Office equipment					
1) Laptop	1	60000	1	60000	
2) Desktop computer	1	60000	1	60000	
3) Printer	1	20000	1	20000	
4) Scanner	1	10000	1	8000	
5) Digital camera	1	25000	1	25000	
6) UPS	1	10000	1	10000	
7) Executive Table	1	20000	1	20000	
8) Executive Chair	1	10000	1	10000	
9) Visitor/front chair	3	12000	3	12000	
10) File cabinet	1	20000	1	19500	
11) Computer table	1	5000	1	5000	

Description of equipment	PP Target		Achievement		Remarks
12) Computer chair	1	3500	1	3500	
(b) Lab &field equipment					
1) HQ 40D Multimeter	1	3500000	1	345000	
2) HACH kit (FF2)	1	1800000	1	175000	
3) Electric Microscope	1	320000	1	320000	
4) Ice Box	2	10000	2	10000	
5) Refrigerator	1	60000	1	60000	
6) S-R Cell	1	5000	1	8000	
(c) Other capital items					
1) Motorcycle	1	175000	1	175000	

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

3. **Training/study tour/ seminar/workshop/conference organized by the sub-project**

Description	Number of participants			Duration (Days)	Remarks
	Male	Female	Total		
BARC component					
Inception Workshop (1)	56	7	63	1 day	All workshops held at the Conference room of BARC as per schedule of activity of the Coordination component
Half yearly Research Prog. Review Workshop (2 no.)	65+ 62	9+8	144	1+1 = 2 days	
Annual Research Prog. Review Workshop (2 no.)	60+63	7+8	138	1+2 =3 days	
Project Completion Report Review Workshop (1 no)	45	6	52	1 day	
Training					
RU component					
PSTU component	20	2	22	01 day	
Workshop					
RU component	56	14	70	1 Day	
PSTU component	-	-	-	-	-
Farmer group discussion					
RU component					Conducted in two sites
a. On carp fattening	18	--	18	05 days	
b. SIS fish farming	-	18	18	05 days	
PSTU component	90	10	100	03 days	
Exchange visit					
RU component	-	-	-	-	-
PSTU component	18	-	18	07 days	

C. Financial and Physical Progress (Combined and component wise)

Financial and physical progress (Combined)

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	7426730	6217369	6216909	460	83.71	
B. Field research/lab expenses and supplies	19734668	19302129	19295258	6871	97.77	
C. Operating expenses	1751611	1600049	1598330.5	1719	91.25	
D. Vehicle hire and fuel, oil & maintenance	1195438	1107859	1107159	700	92.62	
E. Training/workshop/ seminar etc.	162000	162000	162000	0.00	100.00	
F. Publications and printing	340000	285000	285000	0.00	83.82	
G. Miscellaneous	429807	394362	393426.5	936	91.54	
H. Capital expenses	3565500	3563500	3563500	0.00	99.94	
Total	34605754	32632268	32621583	10685	**94.27**	

Coordination component (BARC)

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	502000	502000	502000	0.00	100.00	
b. Field research/lab expenses and supplies	0.00	0.00	0.00	0.00	0.00	
c. Operating expenses	132414	132259	132259	0.00	99.88	
d. Vehicle hire and fuel, oil & maintenance	90951	90951	90951	0.00	100.00	
e. Training/workshop/ seminar.	0.00	0.00	0.00	0.00	0.00	
f. Publications and printing	300000	285000	285000	0.00	95.00	
g. Miscellaneous	49635	49584	49584	0.00	99.90	
h. Capital expenses	225000	225000	225000	0.00	100.00	
Total	**1300000**	**1284794**	**1284794**	**0.00**	**98.83**	

Component -1 (RU)

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	4848671	4176403	4175943	460	86.13	Not applicable
B. Field Research / Lab expenses and supplies	11988013	11680128	11677339	2789	97.41	
C. Operating Expenses	1036331	1000209	998490.	1718	96.35	
D. Vehicle Hire and Fuel, Oil & Maintenance	595932	581353	580653	700	97.44	
E. Training/Workshop/ Seminar etc.	122000	122000	122000	0.00	100.00	
F. Publications and printing	40000	0.00	0.00	0.00	0.00	
G .Miscellaneous	288283	270203	269267	935.	93.40	
H. Capital Expenses	1787000	1785000	1785000	0.00	99.89	
Total	**20706230**	**19615296**	**19608693**	**6603**	**94.70**	

Component -2 (PSTU)

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	2076059	1538966	1538966	0.00	74.13	Not applicable
B. Field research/lab expenses and supplies	7746655	7622001	7617919	4082	98.34	
C. Operating expenses	582866	467581	467581	0.00	80.22	
D. Vehicle hire and fuel, oil & maintenance	508555	435555	435555	0.00	85.65	
E. Training/workshop/ seminar etc.	40000	40000	40000	0.00	100.00	
F. Publications and printing	0.00	0.0;	0.00	0.00	0.00	
G. Miscellaneous	91889	74575	74575	0.00	81.16	
H. Capital expenses	1553500	1553500	1553500	0.00	100.00	
Total	**12599524**	**11732178**	**11728096**	**4082**	**93.08**	

D. Achievement of Sub-project by Objectives (Tangible form): Technology generated/ development

Component -1(RU)

<table>
<tr><th>General/Specific objectives of the sub-project</th><th>Major technical activities performed in respect of the set objectives</th><th>Output(i.e. product obtained, visible, measurable)</th><th>Outcome(short term effect of the research)</th></tr>
<tr><td>Identify good practices and develop sustainable carp fattening technology</td><td>1. Identify good practices and problems in carp fattening
2. Conduct experiments on species combination, stocking density & supplementary feed for carp fattening
3. Organoleptic study to determine the causes of taste variation in carps</td><td rowspan="5">1.Farming practice and associated problems identified
2.Suitable species combination, stocking density and feeding strategy found in carp fattening
3. Suitable species, stocking density and feeding strategy found in SIS fish farming
4. Causes identified for taste variation in carps and technique developed to remove the off flavor
5.Technique found to increase survival rate for live fish transportation
6. Increased capacity of the participating farmers/entrepreneurs
7.Findings disseminated through developing leaflet, creating media coverage, conducting workshop and producing scientific paper</td><td rowspan="5">Increased fish production, consumption and income in the study area</td></tr>
<tr><td>Promote high valued SIS fish farming by the distressed women in homestead ponds</td><td>4. Identify existing farming practices and problems in homestead ponds
5. Conduct experiments on species suitability, stocking density & supplementary feed for SIS fish farming</td></tr>
<tr><td>Develop viable technology for live fish transportation</td><td>6. Conduct experiment on development of live fish transportation technique</td></tr>
<tr><td>Increase capacity of farmers, entrepreneurs and market players</td><td>7. Organize farmer group discussion
8. Organize Field Day</td></tr>
<tr><td>Disseminate findings</td><td>9. Develop scientific paper
10. Develop IEC material (leaflet)
11.Organize findings sharing workshop</td></tr>
</table>

Component -2 (PSTU)

General/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)
To develop sustainable technology for carp fattening by the entrepreneurs in ponds	- Determination of suitable species combination for carp fattening in ponds under coastal area - Stocking density optimization for carp fattening - Suitability of supplementary feed in carp fattening	- Suitable species combination for carp fattening has been identified. - Optimum stocking density of carp has been identified - Effects of supplementary feeds on the production and economics of carp fattening in ponds were developed.	- Improved food security - Increased income and improved livelihoods of farmers
To promote farming of high valued SIS fish by the distressed women in homestead ponds	- Species suitability for SIS fish farming - Stocking density optimization for SIS fish farming. - Suitability of supplementary feed in SIS fish farming	- Magur was identified as suitable species for farming of SIS fishes in homestead ponds. - Optimum stocking density of magur has been determined. - Effects of supplementary feeds on the production and economics of carp fattening and magur in ponds were developed.	- Improved food security of farmers - Increased income and improved livelihoods of farmers
To increase capacity of farmers, entrepreneurs and market players	- Training and group discussion on carp fattening and magur culture - Farmer visit in RU component	- Capacity of fish farmers were strengthened by conducting training, visiting different ponds of component-1 (RU) and group discussion.	- Increased fish production that improved livelihoods of farmers.
To disseminate findings and recommendation through sharing technical reports and scientific publications in popular journals	- Produced video clip on carp fattening technology. - Published news on carp fattening in print and electronic media. - Provided presentation in workshops. - Published scientific articles	- Disseminated findings through video clip, news on print & electronic media, provided presentation and published scientific articles.	- Contributed in national GDP through increased fish production in Bangladesh.

E: Information/Knowledge generated/Policy generated

Information/knowledge generated

- ✓ Knowledge generated on GAP based carp fattening in ponds under drought prone area
- ✓ Information generated on possibility of GAP based carp fattening in ponds under coastal regions of Bangladesh
- ✓ Knowledge on modified live fish (carps) transportation technique generated
- ✓ Knowledge of removal or reducing the off flavor in carps under fattening
- ✓ Culture and management techniques of Magur farming in homestead ponds under drought prone areas and
- ✓ Culture and management techniques of Magur farming in homestead ponds under coastal regions of Bangladesh

F. 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	
Leaflet	-	2	1. Good aquaculture practice based carp fattening in pond (In Bengali); Dr. Md. Akhtar Hossain; Professor, Department of Fisheries; University of Rajshahi. March, 2021 2. Farming of magur in homestead pond (In Bengali), Dr. Md. Akhtar Hossain, Professor; Department of Fisheries;University of Rajshahi. March 2021
Journal publication	-	4	1.Hossain, M.A., Hossain, M.A., Haque, M A., Mondol, M.M.R., Harun-Ur-Rashid, M. and Das, S. K. 2021. Determination of suitable stocking density for good aquaculture practice-based carp fattening in ponds under drought-prone areas of Bangladesh. *Aquaculture*, 547:737485.https://doi.org/10.1016/j.aquaculture.2021.737485 2. Determination of suitable species combination for good aquaculture practice based carp fattening in ponds under drought prone barind area of Bangladesh. *Archives of Agriculture and Environmental Science*, 5(2): 114-122. 3. Optimization of dietary protein level for good aquaculture practice based carp fattening in ponds under drought prone area of Bangladesh. *Archives of Agriculture and Environmental Science*, 6(1): 26-34. 4. Species suitability for small indigenous species (SIS) of fish farming in carp polyculture ponds under drought prone area. *Journal of Fisheries,* 9(2): 92201.
Video		5	Technology brief in Varendra TV (7.4.2021):

Publication	Number of publication		Remarks (e.g. paper title, name of journal,
clip/TV program			https://youtube.com/watch?v=c_0skIqb7M0&feature=share; . Findings sharing workshop news in Channel I (8.4.2021): https://youtube.com/watch?v=flMDJUYD4_U&feature=share; Success story in carp fattening in ATN Bangla (10.01.2021) and BTV (28.04.2021); and Field Day observation in MyTV (28.01.2021)
Newspaper/Popular article		12	Organoleptic study of carps in “The Daily Sonali Sangbad” on 29.10.2020; Magur farming in homestead pond in “The Daily Sokaler Somoy” on 21.03.2021; GAP based carp fattening in pond in “The Daily Sokaler Somoy” on 23.03.2021; Workshop findings sharing in “The Daily Sokaler Somoy” , “The Daily Amar Somoy” and “The Daily Amader Rajshahi” on 24.03.2021; Success story in carp fattening in “ BANGLATRIBUNE.COM” on 20.01.2021, “Bangladesh Protidin” on 20.01.2021; “The Daily Jugantor” on 22.01.2021, The Daily Prothom Alo” on 24.01.2021 and “The Daily Samakal” on 06.02.2021; and Editorial news on carp fattening in “The Daily Prothom Alo” on 25.01.2021
Abstract		1	Findings presented in World Sea Food Congress (WSC),Malaysia during 9-11 September, 2019
PhD thesis	1	-	**Title** Good aquaculture practice based carp fattening in ponds under drought prone area: Suitability of stocking density and supplementary feed; By: Md. Anwar Hossain Department of Fisheries ,Faculty of Agriculture; University of Rajshahi
MS thesis		3	**Titles** 1. Determination of suitable species combination for carp fattening in ponds under south-west coastal zone of Bangladesh 2. Optimization of stocking density for carp fattening in ponds under coastal area of Bangladesh; 3. Optimization of stocking density for farming of walking catfish (*Clariasbatrachus* L.) in homestead ponds under coastal area of Patuakhali

G. Description of generated Technology/Knowledge/Policy

i. Technology fact sheet

Technology fact sheet: 01

Title of the technology: Good aquaculture practice based carp fattening in ponds under drought prone area

Introduction

Carp fattening (production of larger fish under lower stocking density) towards increased fish production within shorter period is gaining popularity in Northern Bangladesh especially in drought prone areas. Live fish transportation and marketing is also encouraged in supplying safe and larger fish (carps) to the consumers. In fact stocking of larger size fishes is recommended to overcome the farming problems (slow growth rate, high mortality and less fish production) of ponds under drought prone area. Primarily, the application of fattening is found with less number of farmers, however, finding benefits of larger fish within shorter period and high market demand of live fishes, more farmers are found to be involved afterwards in spite of having additional cost for water supply and high leased value of the ponds in recent years. On the other hand, excess use of feed and fertilizers by the farmers results in high production cost including farming problems like plankton bloom, fluctuation in pH level, shortage of dissolved oxygen, production of harmful gases, slow growth rate of fishes, high mortality, occurrence of diseases, off flavor in harvested fishes etc. which ultimately results in constraints for the promotion of a low cost environment friendly sustainable carp fattening technology. Therefore, efforts are necessary for the improvement of existing fattening technology with emphasis on combination and density of the carps, appropriate feed and feeding strategy and good aquaculture practice (GAP) aspects.

Description of the technology

a) Pond selection
- Comparatively larger pond
- Suitable water depth of around 1.5-2.0 meter
- Rectangular pond is preferred for effective netting
- Entrance of sufficient sunlight into the pond

b) Pond management
- Remodeling of the embankment for keeping the pond flood free
- Staffing to protect soil erosion
- Removal of the aquatic weeds
- Removal of unwanted fishes and other animals through repeated netting
- Liming (1kg/decimal) for disinfecting the pond and water quality improvement; in addition to liming (2-3 kg/decimal), ash treatment (15 kg/decimal) is required in obtaining good result from ponds under *barind* area

- Enhancing natural feed production through inorganic fertilizer like urea and triple super phosphate (each @150g/decimal) after 5-7 days of liming

c) Fish stocking

Comparatively larger size fishes produced through overwintering are selected for stocking in fattening ponds. Fishes of different layers are stocked into the ponds after 3-5 days of fertlization as follows:

Water layer	Fish species	Stocking density (Individuals/decimal)	Stocking weight (g)
Surface	Catla	3	350-400
	Silver carp	1	300-400
Column	Rui	3	250-300
Bottom	Mrigal	2	300-350
	Carpio	1	250-300

d) Post stocking management

- Fortnightly liming (200-250g/decimal); in addition to liming, ash treatment (10 kg/decimal/month) for ponds under *barind* area
- Regular fertilization with urea and triple super phosphate (each@ 4g/decimal/day)
- Supplementary feeding (25% protein content) @ 2-5% of fish body weight (twice daily, 50% at morning and 50% at afternoon)
- Use of both commercial (70%) and home- made (30%) feed under restricted feeding regime (feed restriction for 4 days per month) to reduce the feed cost

e) Harvesting and live fish transportation

- Stocked fishes can reach the harvestable size (catla and silver carp of 25-3.0 kg; rui, mrigal and carpio of 1.5-2.0 kg) within 5-6 months; fish production can be obtained as 3500-4000 kg/ha/6 months
- Ensure depuration of the harvested fishes for at least 12 hours in circular tank before transportation
- Maintain less load/density (80-100kg fish per ton of water in truck) with water exchange once while transporting the fishes at distant places (250-300 km)

e) Important considerations for good aquaculture practices (GAP)

- No provision of latrine on or beside the pond embankment
- Avoid homestead activities in pod like washing cloth, cleaning utensils etc.
- Avoid bathing in pond
- No entrance of polluted water in pond from outside
- Avoid the application of organic fertilizer like cow dung and poultry dropping
- Regular test for the existence of pathogenic microbial load and heavy metal concentration at safe level

Suitable area/location

- Drought prone and *barind* area

Benefit

a) Fast growth of fish
b) Increased fish production in shorter period
c) Natural or good taste and flavor obtained with harvested fish
d) Very less mortality of fish
e) Increased income with decreased production cost
f) Effective utilization of the ponds under drought prone area and
g) Environment friendly

Name and address of the Researcher

Dr. Md. Akhtar Hossain, Professor, Department of Fisheries, University of Rajshahi
Dr. Md. Mostafizur Rahman Mondol, Professor, Department of Fisheries, University of Rajshahi

Technology fact sheet : 02

Title of the technology: Farming of Magur in homestead ponds in drought prone area

Introduction

Considering the delicious taste, good nutrition and high medicinal value, magur- a small indigenous species is gained very much popularity as a food fish to Bangladeshi people from the time immemorial. This fish can survive out of aquatic ecosystem for a long time due to it's accessory respiratory organ and can provide greater opportunity of marketing in live condition with high price. This fish was naturally abundant in past but destruction of breeding ground due to environmental pollution and other causes results in less availability at present. This indicates the necessity of culture of this species through proper utilization of different water bodies available in the country. Since it has the ability to survive in an adverse environmental condition like low water depth with low oxygen content and high temperature, the seasonal ponds are considered very much suitable for farming of this species. It can be a potential aquaculture species for the effective utilization of the homestead ponds especially under drought prone area. It is possible to address the vulnerability context and reduce the risks through aquaculture development of a nutrient rich, hardy and short cycle species like magur in ponds under drought prone area. The distressed women of this drought prone area can easily utilize the homestead ponds as nutrient and income source through adopting appropriate technique. Although there are both practices of monoculture and polyculture of this species at farmer level, there is a chance of having poor water quality, high mortality and high cost involvement for supplementary feed based farming especially in monoculture. This fish requires high protein content in diet for farming at high density in low space. And thus it is almost found as a challenge for searching an appropriate technique so as to supply a highly nutritious food item like magur to the plate of lower income people. In fact these issues are not considered well in our research system to date. Therefore, efforts are required for the development of a sustainable aquaculture technology of magur in homestead ponds by the distressed women with emphasis on suitable stocking density, appropriate feed and feeding strategy and water quality aspects.

Description of the technology

a) Pond selection

- Comparatively smaller pond
- Suitable water depth of around 1.0-1.5 meter
- Entrance of sufficient sunlight into the pond

b) Pond management

- Remodeling of the embankment for keeping the pond flood free
- Staffing to protect soil erosion
- Removal of the aquatic weeds
- Removal of unwanted fishes and other animals through repeated netting
- Liming (1kg/decimal) for disinfecting the pond and water quality improvement; in addition to liming (2-3 kg/decimal), ash treatment (15 kg/decimal) is required in obtaining good result from ponds under *barind* area
- Enhancing natural feed production through inorganic fertilizer like urea and triple super phosphate (each @150g/decimal) after 5-7 days of liming

c) Fish stocking

Comparatively larger size carps are stocked with the seeds of magur for maintaining good water quality and overall fish production in homestead ponds as follows:

Fish species	Stocking density (Individuals/decimal)	Stocking weight (g)
Magur	300	2-3
Catla	1	200
Silver carp	2	200
Rui	1	100

d) Post stocking management

- Fortnightly liming (200-250g/decimal); in addition to liming, ash treatment (10 kg/decimal/month) for ponds under *barind* area
- Supplementary feeding (35% protein content) @ 2-10% of fish body weight (twice daily, 50% at morning and 50% at afternoon)
- Use of both commercial (70%) and home- made (30%) feed under restricted feeding regime (feed restriction for 4 days per month) to reduce the feed cost

e) Harvesting and production

- Stocked fishes can reach the harvestable size (magur of 100-110g; catla of 800-1000g; silver carp of 1000-1300g; and rui of 60-800g) within 5-6 months
- Fish production can be obtained as 7000-7600 kg/ha/6 months (magur as 6500-7000 kg and carp as 500-600kg)

f) Important considerations

- Fencing the pond embankment with net (minimum height of 3 feet) to protect the fish escape during flood
- Avoid the excess use of lime, fertilizer and feed

- More emphasis on home-made feed application than that of commercial feed
- Since complete harvesting is often found difficult through repeated netting, drain out of water from the pond may be required
- Complete the harvesting before winter

Suitable area/location

- Drought prone and *barind* area

Benefit

a) Shorter culture period
b) Culture at high density in low space
c) Marketing of the harvested fishes at live condition
d) High market price of the harvested fishes
e) Increased income through women participation
f) Supply of nutrient rich food to the family members
g) Effective utilization of the homestead ponds
h) Less cost involvement with high profit margin and
i) Environment friendly

Name and address of the Researcher

Dr. Md. Akhtar Hossain, Professor,
Department of Fisheries, University of Rajshahi
Dr. Md. Mostafizur Rahman Mondol, Professor,
Department of Fisheries, University of Rajshahi

Technology fact sheet : 03

Title of the Technology: Carp fattening technology in ponds of under coastal regions of Bangladesh

Introduction

The fish farming plays an immense significance in the socio-economic context of Bangladesh. Fisheries sector is contributed nearly 3.50% to the gross domestic product (GDP) of our country. It provides for about 60% of the animal protein intake in our daily diet of the people of Bangladesh. Therefore, it is not only met the fulfill demand of animal protein but also it can be economically profitable. Carp fishes are occupied one of the most important place of fish farming in the country. Indigenous and exotic major carps are called carp fish. However, carp fishes are divided into two group viz. major carp and minor carp. Notable, in Bangladesh, rohu (*Labeo rohita*), catla (*Gibelion catla*) and mrigal (*Cirrhinus cirrhosus*) etc. are the main species among the indigenous major carps and silver carp (*Hypophtahalmichthys molitrix*), mirror carp (*Cyprinus carpio* var. *specularis*) and common carp (*Cyprinus carpio* var. *communis*) etc. are most suitable species among the exotic major carps for carp fattening.

The geographical location and environment of Bangladesh is very enriching the fish farming, unfortunately it is also true that we are not able to proper utilize the potentiality of fish farming.

It is possible to get several times higher production compare to present culture system of fish farming only by establishing modern fish farming system. At present, it takes 2-3 years to produce 2-3 kg individual carp fishes by stocking the small size carp fingerlings. However, farmers will be benefitted in a short time, if they culture fish in a planned way through utilizing the potential of modern carp fattening technology. Carp fattening technology reduces the risk and is also profitable for cultivation of carp fishes. It is possible to produce 2.0-3.0 kg fish within 6-7 months through carp fattening technology. The common criteria of carp fishes are as follows:

- High growth rate
- High disease resistance capacity;
- No compete with each other for food and space;
- Parasite cannot attack easily;
- Ensured as natural food is obtained from all layers of water body; and
- It is good taste and delicious to eat.

Description of the Technology

The following steps need to be conducted for fish farming in carp fattening technology.

a. Pond selection

Pond selection is one of the important issues for fish farming. It is the best to have water for 9-10 months and a relatively large size pond is suitable for carp fattening. The ideal size of pond for carp fattening is greater than 35 decimal containing average water depths of 2.0-2.25meter. It is better not to have any leafy trees and shrubs on the banks of the pond. A pond that penetrates adequate sunlight easily should be chosen for carp fattening.

b. Pond preparation

The main purpose of pond preparation is to create a favorable environmental condition for fish farming. The most important things for preparation of a carp fattening pond can be done in the following steps:

1.1.1. Construction of a new pond

The construction of new pond is more convenient for carp fattening, because the pond can be made in a planned way with proper design. The new pond is convenient for fish sampling and harvesting of marketable size fish.

c. Renovation of derelict pond

After sun drying the derelict pond for a week, the banks and the bottom of the pond will have to be repaired. If the bottom of the pond contains huge amount of mud, it should be removed. As a result, the amount of pathogens and harmful gases in the pond will be reduced. Unwanted weeds on the banks of the pond need to be cleaned always.

d. Removal of unwanted fishes

The success of the carp fattening technology is not possible if there are unwanted fishes in the pond. So the unavailability of unwanted fish in the pond must be ensured. It is possible to kill or remove unwanted fish through pond drying or by applying rotenone in appropriate doses. The dose of rotenone is 25-30 g/decimal at a 1 feet water depth of the pond for killing or removing of unwanted fish.

e. Application of lime

The proper doses of lime may vary depending on the pH of the soil and water. If the pH is below 7.5, the lime should be applied 1 kg per decimal of the pond. Lime will mix with water and keep overnight and distribute on the pond surface the next morning.

f. Application of fertilizer

The application of fertilizer in ponds is essential to increase water fertility or nutritional needs. For making natural food, urea and TSP should be applied in the pond at the rate of 200 g/decimal and 100 g/decimal, respectively.

g. Stocking of fingerlings

After pond preparation, the fingerlings will have to be stocked in the pond. Then the good quality, healthy and strong carp fingerlings weighing 300-400 g must be stocked for getting the highest level of production through carp fattening. The carp fingerlings weighing 300-400 g can be collected from local nurseries from March to May. Besides, carp fingerlings weighing 300-400 g should be cultured in the rearing pond on its own initiative and then stocked in the grow-out pond for carp fattening technology. For obtaining the highest level of production, stocking density should be followed 10 carp fingerlings (rui, catla, mrigal, silver carp and common carp) per decimal in the pond. Of the 10 carp fingerlings per decimal, the species combination will be 35% (catla and silver carp), 35% (rui) and 30% (mrigal and common carp) at the upper, middle and bottom layer, respectively.

h. Application and dosages of supplementary diet

- Supplementary feed should be provided in the pond for rapid growth of carp in addition to natural food;
- The success of carp fattening technology is largely depends on the application of quality feed;
- Use quality ingredients and ensure at least 25% protein in the fish feed;
- Commercial fish feed might be collected from the market if anyone cannot make feed by own self;
- Application of fish feed should be provided considering the number and body weight of stocked fishes;
- Fish feed should be supplied at the rate of 3% body weight of stocked fish;
- In winter, fish feed should be supplied at the rate of 2% body weight of stocked fish;

- Restricted feeding i.e. no feeding or fasting once per week i.e. a new dimension of feeding strategy should be followed; and
- Supplementary feed should be adjusted fortnightly by sampling the fishes.

i. Application of Fertilizer

- After stocking fish fingerlings, fertilizer should be applied at the rate of 100 g/decimal and 50 g/decimal of Urea and TSP, respectively, in 15 days interval for producing natural food in ponds;
- Application of fertilizer should be stopped during winter season or excessive green color of water body in pond.

j. Management of Fish

- Water should be supplied from other sources in case of depletion of water level in the pond;
- On the other hand, excessive water should be taken out through outlet if there is a possibility of water overflowing during the rainy season;
- Apply lime as required after checking the pH of water during culture period;
- In addition, lime should be applied at the rate of 500 g/decimal at the beginning of winter so that the fish is not affected by any disease;
- The fish becomes to the above the water surface due to oxygen deficiency in the water and start to gulf the oxygen from the air. In this case, it is necessary to supply oxygen immediately in the water by swimming or by making waves in the pond with a pan or by beating water with bamboo or by using oxygen tablets;
- The horra have to pull sometimes for removing toxic gas from the bottom of the pond; and
- Relatively larger sized fish should be sold in the market.

k. Fish harvesting and production

- The average weight of carp fish will 2.0-3.0 kg after 6-7 months of culture period;
- Use seine net for harvesting;
- Fishes will be harvested in the early morning and to sell in alive condition in the market so that farmers get high price; and
- Maximum yields might be 4.5-5.5 tons/hectare/year possible by utilizing the proper technique of carp polyculture through carp fattening.

l. Problems of carp fattening technology

- High mortality rate occurs when 300-400 g sized fishes transported for stocking of carp fattening;
- The higher the price of fish feed, the higher the production cost; and
- Decomposition of unused fish feed and fish wastes in the bottom of pond resulting oxygen deficiency, creation of ammonia and hydrogen sulfide gas in the water which ultimately fish mortality occurs.

m. Resolve the problems

- Carp fishes weighted 300-400 g should be collected from local nurseries. Besides, carp fish weighing 300-400 g has to be cultured in rearing ponds on its own initiative;
- Stocking density of carp fish not more than 10 individuals/decimal in the pond;
- 25% protein content should be ensured in supplementary fish feed;
- Utilization of excessive fish feed should be avoided;
- Proper doses of lime should be applied to maintain the quality water in time to time;
- Appropriate measures should be taken when fish disease occurs; and
- Live fish might be sold in the market to get high price.

Suitable Area/Location

This experiment was successfully conducted at Nilganj under Kalapara upazilla in Patuakhali. The results of this study suggested that not only the coastal region (Patuakhali, Barguna, Bagerhat, Khulna, Satkhira, Noakhali, Bhola etc.) but also all over the area/location of Bangladesh are suitable for fish farming through carp fattening technology.

Benefits

- It can meet the local demand as well as fish farmers can supply big size carp fishes several areas of the country. Moreover, they can earn a lot of money through self-employed by carp farming which is ultimately helpful to improve or change their livelihood.
- It helps to produce maximum yield or production of carps within very short culture period (6-7 months).
- It helps to increase national fish production level, improve food security, income and livelihoods of fish farmers community through carp fattening.
- In a nutshell, this experiment is helpful to produce big size carp fishes in the coastal area of Bangladesh as well as increase the fish production which is improve the livelihood condition of the coastal fish farmers.

5. Name and Address of the Researchers (including mobile and email)

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Technology fact sheet : 04

Title of the Technology: Culture of Magur in Homestead Ponds of Coastal Regions of Bangladesh

Introduction

Freshwater Magur, *Clarias batrachus* is highly delicious and fast-growing catfish in Bangladesh. In earlier, a large number of native or local Magur fish was found available in natural sources. Now-a-days, the native or local Magur is not found available due to the man-made causes and indiscriminately fishing. In this regard, there is no alternative to culture in the pond for protecting this fish. It can survive easily in adverse environmental condition like shallow water depths, deficiency of oxygen level, polluted water or high-water temperature etc., therefore, there is ample opportunity to culture this fish in seasonal ponds or small size homestead ponds. Traditionally fish farmers cultured this fish both mono and polyculture systems. The potential expansion of Magur culture will provide high quality nutrition to lower-income families. It is necessary to need urgent steps for the sustainable culture and management strategy of highly nutritious and high market demand of Magur fish through the participation of rural women in homestead ponds. This publication is based on the results of field level research in the southern part of Bangladesh. It is hoped that the development of sustainable technology and dissemination of the Magur culture in homestead pond will be helpful to the students, teachers, researchers, extension workers and farmers who involved directly or indirectly in the fisheries sector.

General features of Magur

- Magur fish can be cultured at high stocking density.
- It can be marketed in alive condition.
- The soil, weather and climate of this country are very suitable for catfish culture.
- It can be also cultured at high stocking density in seasonal ponds or shallow ponds.
- It can live comfortably in adverse environmental condition, even in deficiency of oxygen level, polluted water or excessive water temperatures.
- Short marketing period i.e. it is marketable size within 7-8 months.
- It is very nutritious, good taste and delicious to eat.
- High disease resistance capacity and less mortality rate.
- Eco-friendly and can be achieved maximum profit by utilizing minimum cost.

Description of the technology

The following steps need to be conducted for Magur culture in homestead ponds.

a. Pond selection

Pond selection is one of the important issues for Magur culture. The following criteria is need to be considered during pond selection for Magur culture.

- The pond size, 10 to 20 decimals, is better for native or ‘Deshi’ Magur culture;

- The water depth of the pond should be 1.0-1.5 meter; and
- Easily penetrate or provide adequate sunlight in the ponds.

b. Pond preparation

The main purpose of pond preparation is to create a favorable environmental condition for Magur culture. The most important things for preparation of a pond for Magur culture can be done in the following steps:

- To repair bank of the ponds to keep it free from flood and the surroundings of the ponds bank is also covered with net for ensuring protection so that fish cannot escaped from the ponds;
- To eradicate unwanted aquatic weeds from the pond;
- To remove or kill all types of fish through pond drying or by applying rotenone in appropriate doses. The dose of rotenone is 25-30 g/decimal at a 1 feet water depth of the pond for killing or removing of unwanted fish. Then the lime should be applied 1 kg per decimal in the pond;
- The application of fertilizer in ponds is essential to increase water fertility or nutritional needs. After 5 to 7 days of lime application, urea and TSP should be applied at the rate of 200 g/decimal and 100 g/decimal, respectively, for making natural food in the pond; and
- After 3 to 4 days of application of fertilizer, fingerlings should be stocked in the pond after application of disinfectant.

c. Stocking of Magur fry

The good quality magur fry should be collected from local fish hatchery and need to be stocked in the homestead ponds in the morning or evening. It should be stocked after conditioning in the pond water instead of releasing directly. It will reduce the mortality rate of fry. For maintaining water quality and increasing overall production, the fingerlings of carp fishes (relatively large size and old carp fingerlings; weighing 200-300 g) are stocked with Magur in homestead ponds to as follows:

Name of Fingerling	Stocking Density (per decimal)	Weight of Fingerlings (g)
Magur	300	2-3
Catla	1	300
Silver Carp	2	300
Rui	1	200

d. Application of supplementary diet

- Not only required good quality fingerlings of Magur but also required good quality feed for increasing production;

- The balanced pellet diet (containing 30-35% protein) should apply 2-10% of the body weight of fish. At the beginning of culture, to start feeding with 10% of the body weight of fish. As the body weight increases, it should be reduced to at the rate of 2%body weight of stocked fish. For better production, the total amount of daily fish feed should be applied in 2 times a day (50% in the morning and 50% in the evening);
- To increase the production of natural food, 100 g/decimal of urea and 50 g/decimal of TSP should be applied in the pond water in monthly interval during whole culture period;
- For reducing the production cost, the 30% home-made feed (fishmeal 40%, mustard oil 15%, rice bran 20%, wheat bran 20%, binder 3% and vitamin 2%) and 70% commercial pellet feed should be applied; and
- In addition, 'restricted feeding strategy or fasting' i.e. no feeding once per week should be followed to keep good water quality and reduce variable.

e. Fish harvesting and marketing

- For harvesting and marketing of fish, the decision should be taken considering in view of the size and weight of fish, market price, other risks including theft and especially the fish holding capacity of the pond;
- If culture method is managed properly, the individual weight of Magur 90-110 g, Catla 900-1100 g, Silver carp 1200-1300 g, Rui 800-1000 g within 7 to 8 months culture period;
- Fish should be harvested by pond drying; and
- All fishes should be marketed in live condition for getting maximum price.

f. Precautions and important considerations

- In order to prevent the fish escaped in the rainy season, a net of at least 3 feet height should be installed around the pond;
- Lime should be applied as required by checking the pH of water during culture period;
- The normal skin color of the fish does not come on in some times during Magur culture period .It reduces the acceptability of fish to the consumers resulting in lower market prices. To overcome this problem, water hyacinth or water lettuce (locally called topapana) can be given to one-fourth part of the pond at least 15 days before harvesting of fish. However, the water hyacinth or water lettuce should be removed from the pond after harvesting; and
- All fishes should be harvested from the pond before winter season.

g. Impacts of the technology

- The physico-chemical parameters of pond water (temperature, turbidity, total dissolved solids, dissolved oxygen, pH, alkalinity, ammonia and carbon di-oxide) are found in optimum levels; and
- There is no harmful effects on human health and environment rather eco-friendly.

Suitable area/location

This study was successfully conducted at Nilganj and Chakamaiya Union under Kalapara Upazilla in Patuakhali. The results of this study suggested that all over the Bangladesh are suitable for magur culture in homestead ponds.

Benefits

The findings of the present study pioneered that the marketable size of magur can be produced in the homestead ponds of coastal area within very short culture period (6-8 months) of time and the highest net profit was found in BDT 6,96,797.00 per hectare;

- It can meet the local demand as well as can supply catfishes in regional areas of the country. Moreover, local fish farmers especially rural women can earn additional money due to high market price which is ultimately helpful to improve or change their livelihood status;
- In a nutshell, it will helpful to produce more catfishes in homestead ponds which ultimately improving the empowerment of rural women.

5. Name and address of the researchers (including mobile and email)

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ii. Effectiveness in policy support (if applicable): Not applicable

H. Technology/Knowledge generation/Policy support (as applied)

i. Immediate impact on generated technology (commodity & non-commodity)

Participating farmers were capable to increase fish production, consumption and income in the study area. Harvested fishes (carps) were found safe with natural taste (without off flavor) for consumption

ii. Generation of new knowledge that help in developing more technology in future

Technology generated under the present research and the related information will help to develop more advance technologies in the following respective areas:

- Minimizing of cost and safe fish production through increased utilization of underutilized water bodies of draught prone and coastal areas with advance methods of Good Aquaculture Practices.
- Intensification of culture technology to boost up the fish production from homestead water bodies through use of devices for culture and water quality management.
- Development of mechanism for modification and addition of cooling and aeration devices for large water holding tanks in transportation system will allow shipment of more and bigger live species as per consumers demand.

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

- The following technologies from the sub project transferred to the stakeholders through training and field visits/exchange visits those contributed/helped to increase productivity and farmers income:
- GAP based farming allowed fattening of carp species thereby increased production within a justified culture period without application of chemical and inorganics thereby reduces production cost and ensured food safety.
- Live fish transportation and marketed offered better income to the farmers.
- Increased production of SIS with the involvement of women from the homestead ponds offered both utilization and production from the underutilized water bodies, increase nutrition intake through consumption of fish and extra earnings through selling of fish.

iv. Policy Support

- Culture of SIS fish in homestead underutilized and unutilized small water bodies in coastal areas and draught prone areas through involvement family women in aquaculture activities has been proved to be an ideal technology that could contribute to poverty alleviation through self-employment and improvement of socio-economic condition of rural poor families and fulfil the demand of animal protein of the family as well(Clause 3 of National Fish.Policy 1998).
- Improved Technology on carp fattening based on Good Aquaculture Practice (GAP) could be an alternate good earning source for the poor's (Clause 7.0 of NFP, 1998) through extension of the proven technology among the farmers (Claus 10.3,NFP 1998).

I. Information regarding Desk and Field Monitoring

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

Several meetings and workshops were conducted from the beginning of the sub-project to share the project implementation strategy, research progress and problems faced. Necessary feedback was also provided through reviewing the inception, half-yearly and annual reports.

Meetings/workshops	Suggestion/comments	Action
Inception workshops		
RU component	Focus on increasing capacity of the farmer in objectives	Complied
	Inclusion of organoleptic study in methodology	Complied
	Mentioning protein content and feeding frequency in feeding trials	Complied
PSTU component	Baseline information should cover the information in detail on existing fattening practices	Complied
	Rewrite the specific objective 4 of the component as "To increase capacity of farmers, entrepreneurs and market players" by discard the part of the sentence: To train".	Complied
Coordination meetings		
	Experiments on feeding trials on carp culture and SIS culture in homestead pond are to be completed by Nov,20	Completed by Dec,20
	Taste variation study of carps produced through organic and inorganic fertilizer application and survey for generation of data on fish marketing practices should run parallel with other ongoing study activities	Study done accordingly
	Efforts under capacity building efforts for farmers and entrepreneurs should include the topics on post-harvest culture treatment, GAP aspects and general problems of aquaculture and mitigating measures;	Efforts taken accordingly
	Study on fattened live fish transportation trials at different size and density should also consider the impact of temperature, time length of transportation, Ammonia and DO concentration in tank water and survival rate etc.	Study done
1st Annual review workshop		
	Initial wt. of fish (carps and cat fish) stocking between the two components (RU & PSTU) is found highly inconsistence. Need to establish better coordination between the components particularly in regard to size of fish release for selected species	Carps were stocked at 500 g in 2nd experiment)

Meetings/workshops	Suggestion/comments	Action
	and time of release. It was a generally released common size for PSTU while trials should include bigger size fish for stocking (approx. 500 g for carps) as done in case of RU.	
2nd Annual review workshop		
	Sharing of experience of previous year gathered by RU for successful transportation, releasing and fattening of bigger size of carp species in experiment ponds may be followed by the PSTU component.	All project members and few fish farmers of PSTU component were visited sub-project areas of RU component and they gathered huge knowledge from this visit.
	Alternatively, at first step, smaller size fingerlings may be procured and reared in nearby ponds under project care up to a desire size for stocking that may reduce the mortality of big fry due to transportation stress.	It was an excellent idea but was not possible due to many difficulties like natural calamity, shortage of time etc.
	Off and on, data on socio-economic development and SIS production of the rural women involved should be compared by the component PI.	Data compared between two components.

ii. Field monitoring (date & no. of visit, name and addresses of team visit and output) of the sub-projects

Component 1 (RU)			
Monitoring team	**Date(s) of visit**	**No. of visit**	**Output**
Technical Division/ Unit, BARC	25/06/2019 13/03/2020	02	Oriented with Guidelines for carrying out sub-project activities in right tract both in field and on-station.
PIU-BARC, NATP-2	09/11/2020 11/02/2020 22/02/2019	03	Feedback found for conducting different experiments through visiting research ponds/ farmers and participating filed days
Others Visitors DFO, DoFOFRD team, Rajshahi PSTU team Chairman, Dept. Fisheries, RU PSTU team	 30/06/2018 11/02/2020 29/02/2020 02/12.2020 23/03/2021	05	Technology transferred through visiting research ponds and participating field days
Component 2 (PSTU)			
Project Coordinators Unit	09.09.2019 27.01.2021	02	Visited research sites and laboratory. Instructions given by the Coordinator was executed
Technical Division/ Unit, BARC	07.10.2020	01	Visited research field & laboratory; some advice was given; action was taken accordingly
PIU-BARC, NATP-2	10.07.2020	01	Visited research field & laboratory;

			some advice were given; action was taken accordingly.
Internal Monitoring (Dean, FoF)	04.11.2019	01	Visited research field and talk to the stakeholders and encourage them for better management of the fish sanctuary.
Other Visitors Component -1(RU)	04.07.2019 14.11.2019 27.09.2020	03	Visited under exchange program

iii. Weather data, flood/salinity/drought level (if applicable) and natural calamities

A. Three years average weather information of Rajsahi region (2018 -2020)

Parameters	Seasons						Remarks
	Pre-Monson (January – April)		Monson (May – August)		Post Monson (Sept – December)		
	Max	Min	Max	Min	Max	Min	
Av. Rainfall(mm)	45	16	260	196	45	27	
Av. Temperature (^{O}C)	5	23	35	27	29	14	
Av. Humidity (%)	80	67	90	82	80	75	
Flood (year & category)	Not reporting						
Av. Salinity (ppt)	0.4 -0.7						
Natural calamity (Frequency & category)	No reportable natural calamities						

Ref: Ragional Meterological Office, Rajsahi and Water Developmemt Board Office, Rajsahi.

B. Three years average weather information of Patuakhali region (2018 -2020)

Parameters	Seasons						Remarks
	Pre-Monson (January – April)		**Monson (May – August)**		**Post Monson (Sept – December)**		
	Max	**Min**	**Max**	**Min**	**Max**	**Min**	
Av. Rainfall (mm)	127	70	412	234	270	230	
Av. Temperature (^{O}C)	28.7	19.3	29.0	27.5	27.4	20.3	
Av. Humidity (%)	73	63	88	80	87	72	
Flood (year & category)	Strong upstream water pressure and heavy rainfall in September 2018, water level of the rivers have increased and lowland areas, river banks and many parts of the area been marooned..						
Av. Salinity (ppt)	0.8	3.4	0.6	.09	0.5	.08	
Natural calamity (Frequency & category)	Tides due to Cyclone "***Cyclone Fani and Bulbul***" and cyclone "***Amphan***"“inundated low-lying areas and damaged crop in 2019 2020, respectively.						

Ref: BBS yearly report' 20

J. Sub-project Auditing (covers all types of audits performed)

a. Coordination component

Types of audit	Major observation/ issues/objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Financial & Performance Audit by FAPAD on 31.10.19 for the year 2018-2019	No objection raised, found all relevant documents updated as per guideline	313523.00	Financial management of the component found running smoothly till the end of the sub-project. **N**o query or objection raised at any stage of operation by the audit teams.	Financial management & sub-project performance found satisfactory
Financial & Performance Audit by FAPAD on 09.12.20 for the year 2019-2020.	No objection raised, found all relevant documents updated as per guideline	61514.00		Financial management & sub-project performance found satisfactory
Financial & Performance Audit by FAPAD on 11.10.21 for the year 2020-2021.	No objection raised, found all relevant documents updated as per guideline	412512.00		Financial management & sub-project performance found satisfactory

b. Component -1 (RU)

Types of audit	Major observation/ issues/ objections raised; If any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Financial & Performances audit by the FAPAD Audit Team	No objection raised by the audit team	6486461.50	Sub project financial management was found satisfactory	FAPAD Audit (2018-2019) on 28.10.2019
Financial & Performances audit by the FAPAD Audit Team	No objection raised by the audit team	6732508.50	Sub project financial management was found satisfactory	FAPAD Audit (2019-2020) on 08.12.2020
Financial & Performances audit by the FAPAD Audit Team	No objection raised by the audit team	6390091.00	Sub project financial management was found satisfactory	FAPAD Audit (2020-2021) on 12.10.2021

c. Component -2 (PSTU)

Types of audits	Major observation/ issues/ objections raised; if any	Amount of Audit (Tk.)	Status at the sub-project end	Remarks
Financial & Performances audit by the FAPAD Audit Team	No objection raised by the audit team-	5264285.00	Sub project financial management was found satisfactory	FAPAD (2017-2018, 2018-2019)
Financial & Performances audit by the FAPAD Audit Team	No objection raised by the audit team-	4375475.00	Sub project financial management was found satisfactory	FAPAD (2019-2020)
Financial and Performance Audit by CA farm	No objection raised by the audit team-	4375475.00	Sub project financial management was found satisfactory	M.I. Chowdhury and Co. (2019-2020)
Financial & Performances audit by the FAPAD Audit Team	No objection raised by the audit team-	2108330.00	Sub project financial management was found satisfactory	FAPAD (2020-2021) on 12.10.2021

K. Lessons Learned

i) Appropriate species, density and feeding strategy improved water quality, yield and benefit in carp fattening and SIS fish farming in ponds under drought prone area.
ii) Practice of GAP for producing safe fish with natural taste (without off flavor).
iii) Lower loading density reduced the ammonia level and increased the survival rate in live fish (carps produced under fattening) transportation.
iv) Local supply of over wintered carps was considered essential for carp fattening in coastal area.
v) Partial harvest of carps might be done for getting fair price.
vi) Pre-caution should be taken for preventing fishes from the nursery/experimental ponds during natural calamity.

L. Challenges

i) Judicial use of feed and fertilizer was important consideration during the period of temperature fluctuation (especially during high temperature) in carp fattening ponds under drought prone area
ii) Risks like price fall of harvested fishes and unavailability of inputs and labor were considered well during early stage of corona pandemic as reported by the farmers in the study area.
iii) Production of over wintered carps was essential in carp fattening for coastal area.

iv) Partial harvest of carps might be done for getting fair price.
v) Pre-caution should be taken for preventing fishes from the nursery/experimental ponds during natural calamity.

M. Suggestions for Future Planning

i) Multi location testing is required for the technologies generated.
ii) More training and workshops are required for effective dissemination of the information/technologies generated
iii) Over wintering carp fingerlings (300-400g) should be produced locally to sustain the carp fattening technology.
iv) Future research should be taken on restricted feeding i.e. no feeding once per week to adopt a new technology by the stakeholders.

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Signature of the Coordinator	**Counter signature of the Head of the organization/authorized representative**
(Dr. Md. Monirul Islam)	***(Dr. Shaikh Mohammad Bokhtiar)***
Date: 17 November 2021	Date: 17 November 2021
Member Director (Fisheries)	***Executive Chairman***
Bangladesh Agricultural Research Council	***Bangladesh Agricultural Research Council***

Appendices

Coordination component

Appendix – BARC: A

Recommendation of the inception workshop and status of action taken

Recommendations	Action Taken
Component 1 (RU)	
• Composition of fish feed (commercial, homemade and mixed type) are to be exposed.	Necessary action taken
• Farmers training, rally, field days are to be used as effective means for technology dissemination;	Recommendation followed
• Rewrite the specific objective 4 of the component as "To increase capacity of farmers, entrepreneurs and market players" by discard the part of the sentence :To train";	Correction done
• Attention should be given to establish Good Aquaculture Practices (GAP) under the guidelines of respective policy paper;	Has been done following respective policy guidelines
• Find out the causes of degradation of some organoleptic (taste, smell, color etc) characteristics of the fishes in greater Rajshahi region	Followed accordingly
Component 2 (PSTU)	
• Specify the variation between the traditional fish fattening practices and the present improved fattening attempts under the research.	Specifies the variation in the next report
• Note the justification of study the presence of heavy metals.	Justification showed in the respective part
• Relationship of culture system, management practices, ecological characters/factors of the water body and other causes with the development of off flavor and tastelessness in cultured fishes are to be find out.	Action taken as per recommendation

Appendix – BARC: B

Recommendation of the half yearly workshops

Recommendations of the First Half Yearly Workshop	Action taken
Component 1 (RU)	
• Nearby authorized fish seed farms should be given priority for quality fish seed collection for the project ponds	Action taken as per suggestion
• Increasing involvement of household women in SIS culture in homestead ponds emphasized	Done accordingly
Component 2 (PSTU)	
• The component of the sub project is running behind the schedule of project activity plan. The PI should take special attempt to speed up the activity of the project.	Necessary action taken.

Appendix – BARC: C

Recommendation of the Annual workshop

Recommendations of the First Annual Workshop	Action taken
Component 1 (RU)	
• Results of baseline study not presented in the workshop	Baseline study done separately.
• Initial wt. of fish (carps and cat fish) stocking between the two components (RU & PSTU) is found highly inconsistence. Need to establish better coordination between the components particularly regarding size of fish release for selected species and time of release. It was a generally released common size for PSTU while trials should include bigger size fish for stocking (approx.. 500 g for carps) as done in case of RU.	Size of fish released and time was adjusted from the second experiment
• Trials for SIS culture development as a new possible technology should preferably be done in the upazilas where this type of practice does not exist;	Selection of experimental household done as per recommendations
Component 2 (PSTU)	
• Baseline did not showed type of fish species used in the culture system;	Included in the next presentations
• Under the fattening program: Stocking density of fish (under expt. No- 1 & 2) not showed that mislead the presentation;	Necessary correction done in the next presentation
• Initial wt. of fish (carps and cat fish) stocking between the two components (RU & PSTU) is found highly inconsistence. Need to establish better coordination between the components particularly in regard to size of fish release for selected species and time of release. It was a generally released common size for PSTU while trials should include bigger size fish for stocking (approx.. 500 g for carps) as done in case of RU.	Adjustment done in consultation and coordination with the other component
Recommendations of the Second Annual Workshop	**Action taken**
Component 1 (RU)	
• As per description of achievements, it seems that feed cost, lease money, operation/management cost and fish fry cost will cover approximately 90% of total experimental culture activity. This statement may grow disinterest among the other farmers. Therefore, critical revision of the report suggested.	Revision done and necessary correction made
Component 2(PSTU)	
• Physical properties of the base line surveyed ponds and nature of water bodies under utilization for carp fattening are not found consistent with the survey findings which may mislead the final findings. This needs thorough checking and necessary correction.	Recommendation followed
• Fish species under fattening and SIS program and the period of culture covered were not shown anywhere of the respective tables. Therefore, it became difficult to understand the species specific performance under both of the cases.	Recoding if information done properly as per comment

Appendix – BARC: D

Recommendation of the coordination meetings

Central Coordination meeting at BARC	
Recommendations	**Action taken**
• Sharing of experience of previous year gathered by RU for successful transportation, releasing and fattening of bigger size of carp species in experiment ponds may be followed by the PSTU component.	It is not applicable for PSTU component
• Alternatively, at first step, smaller size fingerlings may be procured and reared in nearby ponds under project care up to a desire size for stocking that may reduce the mortality of big fry due to transportation stress.	Necessary action taken only by the RU component
• Implementation of some of the recommendations of the review workshop or on-going field activities demands few new areas of research or analysis. In such a situation re-appropriation of budget to meet the research demand become an obligation that requires concurrence of the PIU authority. Respective PI will take initiative in the matter and the Coordination section will provide necessary support.	Information transmitted to the PIU authority through sub-project Coordinator
• Off and on, data on socio-economic development and SIS production of the rural women involved should be compared by the component PI.	Followed through occasional joint meetings and field visits
Two Other virtual Coordination meetings	
Component 1 (RU)	
• Experiments on feeding trials on carp culture and SIS culture in homestead pond are to be completed by Nov;20;	Followed accordingly
• Study on fattened live fish transportation trials at different size and density should also consider the impact of temperature, time length of transportation, Ammonia and DO concentration in tank water and survival rate etc;	Followed accordingly
• Test variation study of carps produced through organic and inorganic fertilizer application and survey for generation of data on fish marketing practices should run parallel with other ongoing study activities.	Recommendation fulfilled partially.
• Efforts under capacity building of farmers and entrepreneurs should include the topics on post-harvest culture treatment, GAP aspects and general problems of aquaculture and mitigating measures.	Considered and included all the subjects recommended
Component 2 (PSTU)	
Baseline need to be enriched with more relevant information along with researchers observation;	Recommendation followed
Immediate starting of feeding trials experiments urged. Trials should not only on feed types and dose but also suggested to study alternate feeding schedule maintaining content of protein and required level and cost – benefit should be analysed.	Special attention focused on the recommended areas
Site by site, transportation of live fattened fish should be carried out maintaining distance not less than 150 Km with one ton capacity carrier. It is suggested to cover the study of impact of other factors as mentioned in case of RU component.	It is not applicable for this component
Proper attention for the development of research based scientific papers and extension manuals emphasized for both the components.	Proper attention given and number of publication done so far





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