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Development of low cost weed based aquaculture technology in ponds

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DEVELOPMENT OF LOW COST WEED BASED AQUACULTURE TECHNOLOGY IN PONDS

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DEPARTMENT OF FISHERIES
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Dedicated

To My

Beloved Parents

DECLARATION

I do hereby declare that the research work submitted as a thesis entitled **"**Development of low cost weed based aquaculture technology in ponds**"** in the Department of Fisheries, University of Rajshahi, Bangladesh for the Degree of Doctor of Philosophy is the result of my own investigation. The thesis or part of it has not been submitted to any other University or institution for any degree.

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ABSTRACT

Three experiments were conducted during 2010-2012 towards the development of low cost weed based aquaculture technology in ponds. Experimental ponds were located at Kushtia district, Bangladesh. In experiment-1, six different conventional and non-conventional fish feed items like rice bran, wheat bran, mustard oilcake, Azolla, grass and banana leaves were tested to determine the nutrient contents (protein, lipid and carbohydrate) under 6 treatments as T_1, T_2, T_3, T_4, T_5 and T_6, respectively. Considering the nutrient content in experiment-1, experiment-2 evaluated the fish production and economics under 4 treatments of feed and weed based system with a similar stocking density of 11115 fish/ha in polyculture ponds as T_0: ponds fed with conventional feed like rice bran, wheat bran and mustard oilcake (no weed was used as fish feed), T_1: Azolla (*Azolla pinnata*) fed ponds, T_2: Grass (*Cynodon dactylon*) fed ponds and T_3: Banana (*Musa acuminata*) leaf fed ponds. Based on the performance of weeds and feeds in experiment-2, experiment-3 optimized the stocking density for Azolla based carp polyculture system in ponds under 3 different treatments of stocking densities like T_1: 9880 fish/ha, T_2: 11115 fish/ha and T_3: 12350 fish/ha. Nutrients in weeds and feeds were compared for a period of 6 months (April to September) in experiment-1. Fishes (*Hypophthalmichthyes molitrix, Catla catla, Labeo rohita, Cirrhinus cirrhosus, Cyprinus carpio, Ctenopharyngodon idella* and *Barbonymus gonionotus*) were also grown for a period of 6 months (April to September) in experiment-2 and experiment-3. Mean initial stocking weight of *H. molitrix*, *C. catla*, *L. rohita*, *C. cirrhosus*, *C. carpio*, *C. idella* and *B. gonionotus* were 62, 64, 57, 54, 63, 65 and 25 g, respectively for experiment-2 and 60, 65, 58, 52, 61, 70 and 22 g, respectively for experiment-3. There were 3 replications for each treatment under different experiments. Liming (250 kg/ha) and basal fertilization (cowdung: 1500 kg/ha, urea: 60 kg/ha and TSP: 60 kg/ha) were done for all the treatments under experiment-2 and experiment-3. Urea (2.5 kg/ha/day in all treatments except treatment T_1 under experiment-2 and in no treatment under experiment-3) and TSP (2.5 kg/ha/day in all treatments under experiment-2 and experiment-3) were applied as periodic fertilization. In case of experiment-1, nutrient contents (protein, lipid and carbohydrate) were monitored monthly whereas in case of experiment-2 and experiment-3, water quality parameters (water temperature, transparency, DO, pH, alkalinity and free CO_2) were monitored fortnightly and fish growth parameters (weight gain and SGR) were monitored monthly. Economics (in terms of total cost, gross benefit, net profit margin and CBR) of fish farming were also evaluated for both experiment-2 and experiment-3. In **experiment-1**, significant variations ($P<0.05$) were found in the mean values of nutrient contents with different treatments of feed items but in case of same feed item no significant difference was found in the nutrient content at different months. Among the non-conventional feed items treatment T_4 (Azolla) varied more significantly ($P<0.05$) for the mean values of protein content. In **experiment-2**, no significant difference in the mean values of water quality parameters were found among the treatments. Treatment T_0 varied more significantly ($P<0.05$) for the mean values of SGR, weight gain, final weight, survival rate and total yield but in terms of total cost, gross benefit, net benefit, net profit margin and CBR, treatment T_1 (Azolla fed pond) was found best. In **experiment-3**, no significant difference in the mean values of water quality parameters were found among the treatments. Significant difference ($P<0.05$) with the treatments were found in all the growth parameters except survival rate. Treatment T_3 varied more significantly ($P<0.05$) for the mean values of total yield but in terms of total cost, gross benefit, net benefit, net profit margin and CBR, treatment T_1 (stocking density of 9880 fish/ha) was found best. Findings indicated that the stocking density of 9880 fish/ha could be a good option for low cost Azolla based fish farming in Bangladesh.

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ABBREVIATIONS

ANOVA	=	Analysis of Variance
BDT	=	Bangladeshi Taka
CBR	=	Cost-Benefit Ratio
CO_2	=	Carbon-dioxide
RCBD	=	Randomized Completely Block Design
DMRT	=	Duncan Multiple Range Test
DO	=	Dissolved Oxygen
DoF	=	Department of Fisheries
DWRP	=	Duckweed Research Project
GDP	=	Gross domestic production
SGR	=	Specific growth rate
SPSS	=	Statistical Package for Social Science
TSP	=	Triple Super Phosphate

GLOSSARY

Baor	=	Dead arms of river which is confined
Bana	=	Bamboo fencing
Beel	=	Natural shallow depression connected to open waters
Haor	=	Saucer-shaped floodplain depressions
Lac	=	100 thousand
PRISM-Bangladesh	=	Non-government Organization
Upazila	=	Sub district

CHAPTER ONE

GENERAL INTRODUCTION

1.1: Present status of the fisheries sector in Bangladesh

Fisheries sector plays an important role in providing income, employment, nutrition and earning foreign exchange in Bangladesh. It has significant role in the improvement of the socio-economic condition of poor fisherman. The fisheries sector contributes 4.39% of the gross domestic product (GDP), 22.76% of agricultural resources and 2.46% of foreign exchange earning of Bangladesh. Fish alone contributes about 60% of total animal protein intake. More than 10% of total populations of Bangladesh are directly or indirectly dependent on fisheries sector for their livelihoods. It provides full time employment to 14.6 million in fishing and other activities related to fisheries (DoF, 2013).

Fish and Fisheries have been an essential part of the life and culture of the people of Bangladesh. Bangladesh is uniquely rich and diverse in water resources. It has innumerable water bodies including ponds, tanks, lakes, rivers, *haors*, *baors*, *beels*, estuaries and inundated paddy fields. Due to favorable climatic condition, the water bodies of Bangladesh are found highly productive and aquaculture is found as an important commercially viable activity (DoF, 2011). The country is blessed with vast inland waterbodies comprising 2710,766 ha of floodplains, 8,53,863 ha of rivers and estuaries, 1,14,161 ha of beels (natural shallow depression connected to open waters), 68,800 ha of man-made reservoir (Kaptai Lake), 3,71,309 ha of ponds and ditches, 5,488 ha of oxbow lakes and 2,75,232 ha of shrimp farms. These water resources offer great scope and potential for augmenting fish production by adopting culture based fisheries techniques (DoF, 2013) (Fig. 1.1 and 1.2).

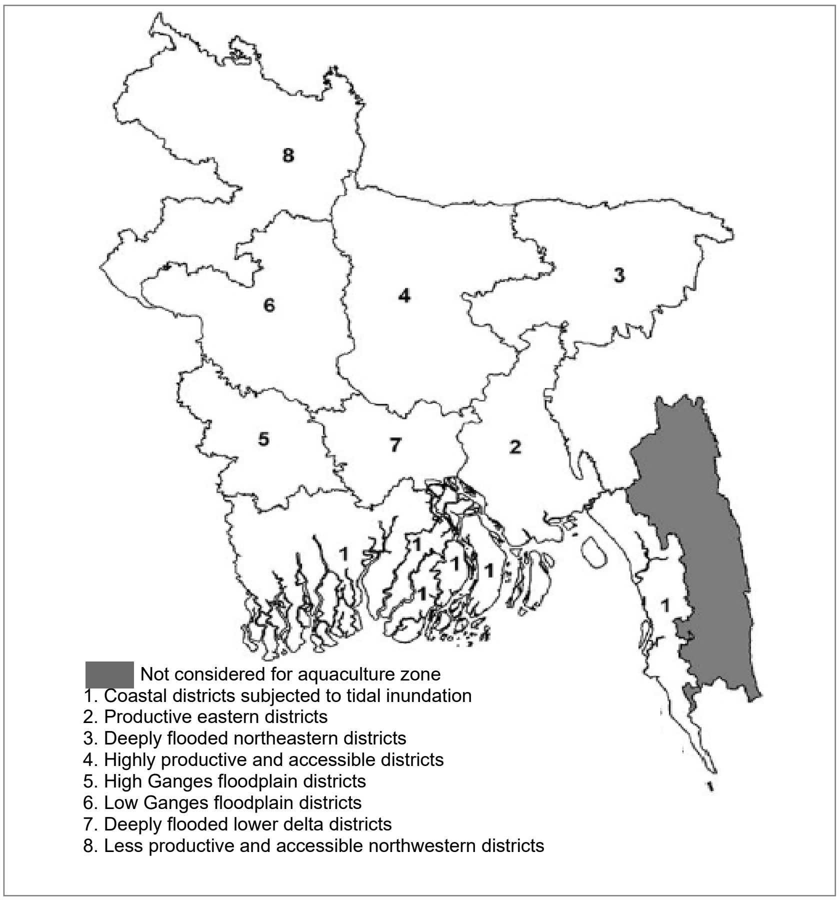


Fig. 1.1: Aquatic regions of Bangladesh (Source: Dey *et al.*, 2008)

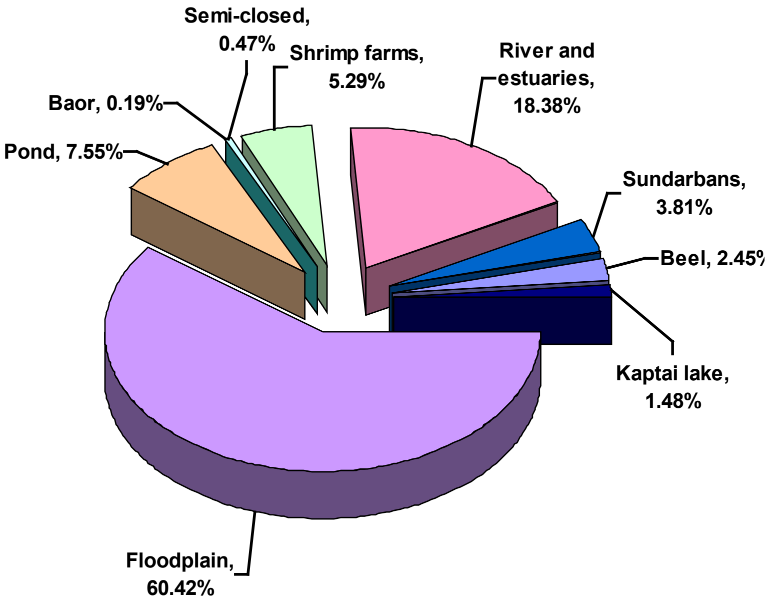


Fig. 1.2: The relative share of different inland waterbodies in Bangladesh (Source: DoF, 2013)

Total fish production in our country during the year 2011-2012 was about 3.26 million metric tons of which 2.68 million metric tons was produced from freshwater including culture fisheries and 0.57 million metric tons from marine water (DoF, 2013) (Fig. 1.3).

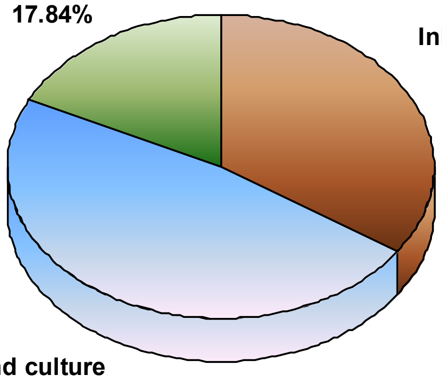


Fig. 1.3: Percentage composition of fish production in capture, culture and marine fisheries (Source: DoF, 2013)

There are indications that the production from capture fisheries decreased recently which increased pressure on aquaculture to fill up the gap. Causes for decreasing capture fisheries production include habitat destruction, unplanned construction of flood control barrages, water abstraction for irrigation, over-fishing and reclamation of land for agriculture. Concurrently, aquaculture production increased due to the development and implementation of improved culture techniques and expansion of the pond culture area (Gupta *et al.*, 1999; Alam and Thomson, 2001).

Inspite of having very rich fisheries resources, the present fish production of Bangladesh is unable to meet the demand of fish intake for the increasing population of the country. The need of annual per capita fish intake is 20.44 kg while the amount produced is 18.94 kg (DoF, 2013). This situation clearly indicates the necessity of creating more attention on the aquaculture operation of the country.

1.2 Potentials, problems and challenges of aquaculture in Bangladesh

Global production of fish from aquaculture has grown rapidly over the past four decades, contributing significant quantities to the world's supply of fish for human consumption. Aquaculture now accounts for almost half (45%) of the world's food fish. With its continued growth, it is expected that aquaculture will, in the near future, produce more fish for direct human consumption than capture fisheries. Aquaculture, which started as primarily an Asian freshwater food production system, has now spreaded over all continents, encompassing all aquatic environments and using a range of aquatic species. From an activity that was principally small scale, non-commercial and family based, aquaculture now includes large-scale commercial and industrial production of high-value species that are traded at national, regional and international levels. Although production remains predominantly in Asian countries and is still largely based on small-scale operations, there is a wide consensus that aquaculture has the potential to meet the growing global demand for nutritious food fish and to contribute to the growth of national economies, while supporting the sustainable livelihoods of many communities (FAO, 2006). Globally, Bangladesh reaches 6^{th} position in producing fish (Table 1.1) and yearly total fish production of Bangladesh is also increasing smoothly (Fig. 1.4).

Table 1.1: Top 20 food fish aquaculture producing countries

Country	Production (1000 tonnes)	Percentage
China	32 414	67.3
India	2838	5.9
Viet Nam	1437	3.0
Indonesia	1197	2.5
Thailand	1144	2.4
Bangladesh	**882**	**1.8**
Japan	746	1.5
Chile	698	1.5
Norway	657	1.4
Philippines	557	1.2
Egypt	540	1.1
Myanmar	475	1.0
United States of America	472	1.0
Republic of Korea	436	0.9
Taiwan, Prov. of China	305	0.6
France	258	0.5
Brazil	258	0.5
Spain	222	0.5
Italy	181	0.4
Malaysia	176	0.4
Rest of the world	225	7 4.7
World total	**48150**	**100.0**

Adapted from Subasinghe *et al*. (2009)

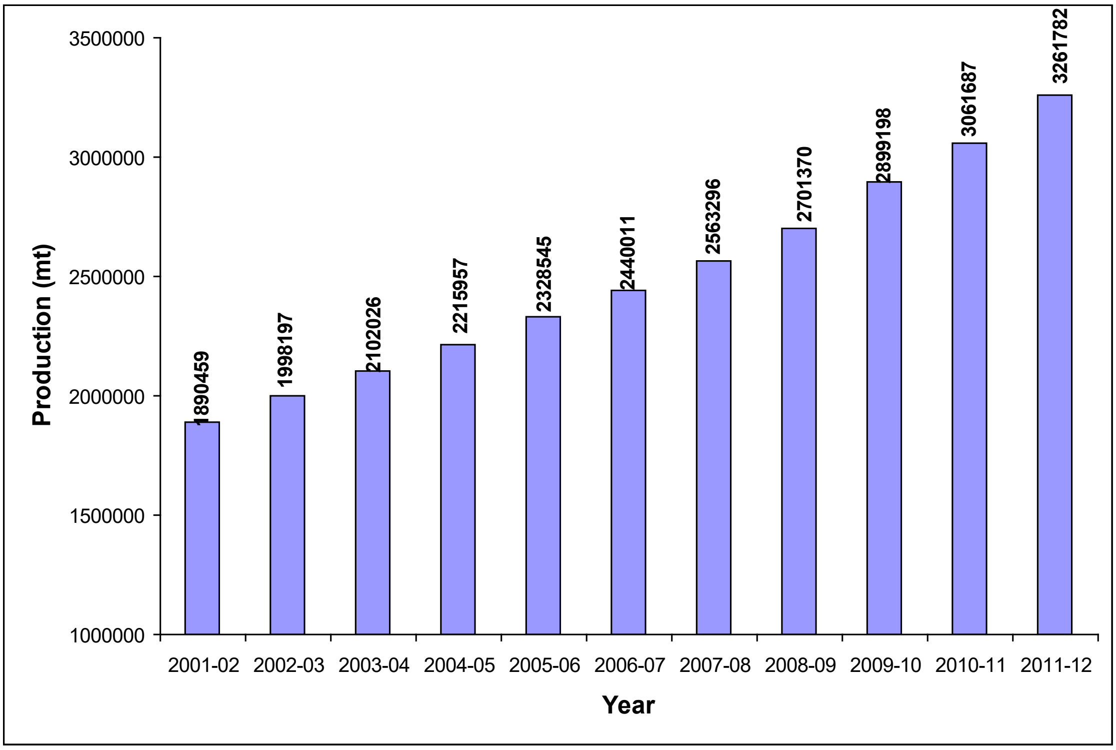


Fig. 1.4: Fish Production trends from 2001-02 to 2011-12 (Source: DoF, 2013)

The different fish farming production systems are generally distinguished according to their degree of intensification which is itself usually defined according to the feeding practices as food represents more than 50% of the total operating costs in intensive systems. However, intensification (or, inversely, extensification) involves many other production factors, such as water, land, capital, and labor (Khan *et al*., 2009).

The main carp species cultivated in the world are primarily seven in number and are often grouped on the basis of their natural geographical occurrence: the so-called Chinese carps, which include the grass carp, *Ctenopharyngodon idella*, the silver carp, *Hypophthalmichthys molitrix,* and the bighead carp, *Aristichthys nobilis,* and the so-called Indian major carps, which include catla, *Catla catla*, rohu, *Labeo rohita,* and mrigal, *Cirrhinus cirrhosus*. The seventh species is the common carp, *Cyprinus carpio*. Taxonomically, carps belong to the family of *Cyprinidae* (order, Cypriniformes) (Azad *et al*., 2004).

Aquaculture in Bangladesh has rapidly progressed in recent years with a contribution of 44% to the annual fish production (Talukdar *et al*., 2012). Among different techniques of aquaculture, polyculture is found as one of the most important techniques. The basic principle of fish polyculture system depends on the idea as compatible species of different feeding habits are cultured together in the same pond, the maximum utilization of all natural food sources takes place without harmful effects. Polyculture or mixed culture of carps has been found as an economically viable and technically sustainable in perennial water bodies (Alikhuni, 1957; Chen, 1976). The selection of fish species is very important for polyculture systems. Generally silver carp (*Hypophthalmichthys molitrix*), catla (*Catla catla*), rohu (*Labeo rohita*), mrigal (*Cirrhinus cirrhosus*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*) and sharpunti (*Barbonymus gonionotus*) are selected for polyculture. Carps are the most important species for pond culture. Three major Indian carps rohu (*Labeorohita)*, catla (*Catla catla*) and mrigal (*Cirrhinus cirrhosus*) and one exotic carp (silver carp, *Hypophthalmichthys molitrix*) accounted for about 80% of pond fish production. Carp species have a vital role in national fish production in Bangladesh. In 2010-11 fiscal year carp species comprised 34.61% of the total fish production (DoF, 2012) (Fig.1.5).

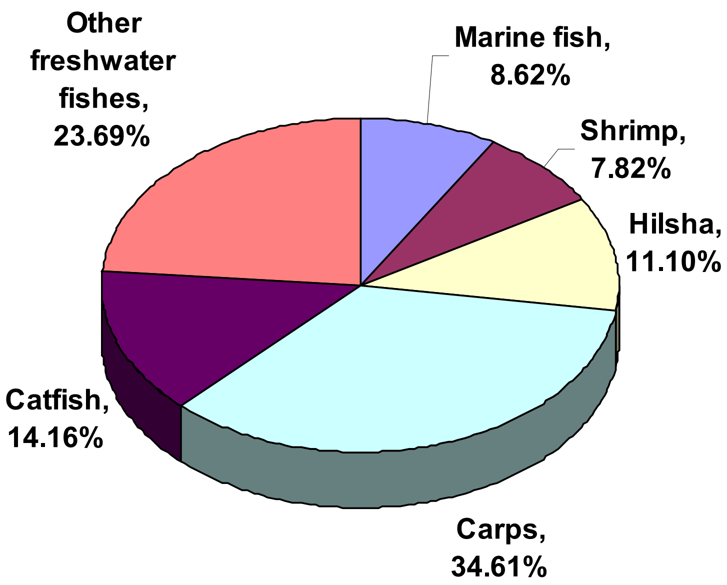


Fig. 1.5: Species group based fish production in Bangladesh (Source: DoF, 2012).

These species are suitable for low inputs culture system in small ponds and ditches for their quick growth and for maximum production within short period. Freshwater fish-culture systems practiced in Bangladesh can be categorized into four groups: carp polyculture, mixed culture, monoculture and integrated fish culture. Mixed culture of fish is a type of polyculture in which carp and some other species are cultured together. In integrated systems, fish culture is integrated with other agricultural enterprises, such as rice-fish farming, rice-fish-duck farming, and fish-poultry farming. Polyculture of Indian and Chinese carps along with a few other exotic species is the most dominant system in Bangladesh. Other practices include pond monoculture of Thai pangus, mixed culture of Nile tilapia and carps in seasonal ponds or ditches, and culture of carps (mainly mirror carp) and silver barb in rice fields. Monoculture of genetically improved Nile tilapia in ponds is also becoming popular, particularly among commercial producers (Dey *et al*., 2008). The possibilities of increasing fish production per unit area, through carp polyculture are found highest when compared with other systems (Table 1.2).

Table 1.2: Geographical distribution in adoption and coverage of fish culture system by culture pattern in Bangladesh.

Major cultural pattern	% of Upazilas adopting culture system				Upazilas adopting system (%)
	Extensive	Improved extensive	Semi-intensive	Intensive	
Carp polyculture	13.7	64.8	41.0	1.1	100.0
Carp polyculture with pangus	11.9	42.5	32.6	2.6	82.2
Pangus monoculture	7.5	22.2	31.9	5.5	63.2
Carp-golda mixed culture	12.6	27.8	14.1	1.1	49.8
Tilapia monoculture	15.9	29.5	26.9	2.2	68.9
Other culture patterns	6.6	15.9	11.9	2.0	33.7

Source: Dey *et al*., 2008.

Different species combination in polyculture system effectively contributes also to improve the pond environment. Algal blooming is common in most tropical manure fed ponds. By stocking phytoplanktophagus Silver carp in appropriate density certain algal blooming can be controlled. Grass carp on the other hand keeps the macrophyte abundance under control due to its macrovegetation feeding habit and it adds increased amount of partially digested excreta which becomes the feed for the bottom dweller coprofagous common carp. The bottom dwelling mrigal, common/mirror carp help re-suspension of bottom nutrients to water while stirring the bottom mud in search of food. Such an exercise of bottom dwellers also aerates the bottom sediment. All these facts suggest that carp polyculture is the most suitable proposition for fish culture in tropical ponds (Dey *et al*., 2008).

Carp polyculture in Bangladesh may be characterized as semi-intensive, with high fingerling stocking rates and low use of feed and fertilizer (Fig. 1.6). Fish farmers generally use less supplementary feed and other inputs compared with their counterparts in countries with more advanced aquaculture systems, such as China and Thailand (Dey *et al*., 2008). It is true that feed expenditure is about 60%-80% of total fish production cost. To decrease this production cost it is essential to minimize the cost for fish feed (DoF, 2010). The major challenge for further promotion of carp polyculture is to reduce the fish feed cost which indicates for the development of low cost aquaculture technology using terrestrial and aquatic weeds as fish feed.

Major aquaculture problems in Bangladesh includes the lack of quality seed and low cost feed, poor water quality, disease and parasites (DoF, 2003).

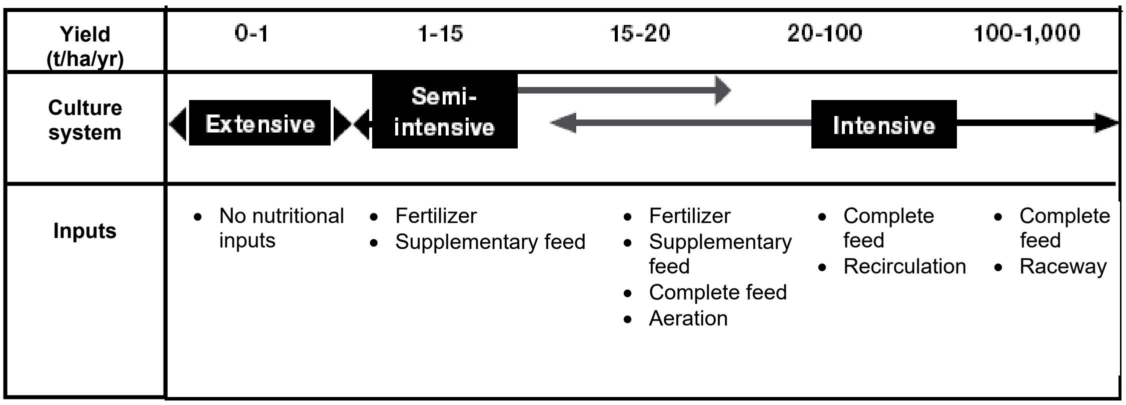


Fig. 1.6: Intensification of aquaculture and potential incremental yield
{Source: Dey *et al*. (2008) which is modified from Edwards (1993)}.

1.3: Importance of low cost aquaculture technique in Bangladesh

Fish feed generally constitutes 60–70% of the operational cost in intensive and semi- intensive aquaculture system (Singh *et al*., 2006). The fish feed used in aquaculture is quite expensive, irregular and short in supply in many third world countries. These feeds are sometimes adulterated, contaminated with pathogen as well as containing harmful chemicals for human health. Naturally there is a need for the development of healthy, hygienic fish feed which influences the production as well as determines the quality of cultured fish (Bag *et al*., 2011). Considering the importance of nutritionally balanced and cost-effective alternative diets for fish, there is a need for research effort to evaluate the nutritive value of different non-conventional feed resources, including terrestrial and aquatic macrophytes (Edwards *et al*., 1985, Wee and Wang, 1987, Mondal and Ray, 1999). The aquatic weeds have been shown to contain substantial amounts of protein and minerals (Ray and Das, 1995). Aquatic and terrestrial macrophytes have been used as supplementary feeds in fish farming since the early times of freshwater fish culture (Bardach *et al*., 1972) and still play an important role as fish feed in extensive culture systems (Edwards, 1987). Since the fish production is found not yet sufficient to meet up the existing demand, further promotion of aquaculture is required specially for the poor who are unable to receive the high cost feed based aquaculture technology. Hence weed based system may be a good option as a low cost, environment friendly sustainable aquaculture technique in Bangladesh (Grover *et al*., 2000).

1.4: Weed based aquaculture system and its history

The weed based system refers to the use of some inputs from plant sources, eg., weeds or grasses or leaves or macrophytes like duckweeds, Azolla etc. (Table 1.3 and Plate 1.1) as supplemental feed in fish production. These inputs are consumed first as feed by herbivorous fish and subsequently a part of the semi digested faecal matter of the macrophytes feeding fishes are consumed by the other fishes and the remaining part will be recycled in food chain as nutrients for primary production, thus they have potentiality to increase the total fish production of aquaculture system. Aquatic plants have been utilized as food components and thus have played an important role in culture of herbivorous fish since 4000 years ago in Egypt and 2500 years ago in the Orient, including Indian subcontinent (Bardach *et al*., 1972). Duckweeds might be having as much potential as fish foods that could be utilized in preparation of suitable fish feed essential in expansion of low-cost aquaculture system in the tropics (Hassan and Edwards, 1992). Since long *Azolla pinnata* utilized as biofertilizer in agriculture has been popular among farmers. Nowadays, its utility in pisciculture has come to limelight and has been proven worthy of note because of its two unique activities: capable of nitrogen fixation from atmosphere that enhances nitrogen in semi-intensive pisciculture systems (Ayyappan *et al*., 1993) and used as direct food by some macrophagous fish (Cassani, 1981; Antonie *et al*., 1987). Fresh duckweed (and also the dried meal) is suited to intensive production of herbivorous fish (Gaiger *et al.,* 1984*)* and duckweed is converted efficiently to live weight gain by carp and tilapia (Van-Dyke and Sutton*,* 1977; Hepher and Pruginin, 1979; Robinette *et al.,* 1980; Hassan and Edwards, 1992; Skillicorn *et al*., 1993).

Table 1.3: Aquatic macrophytes used as fish feed in weed based aquaculture

Sl. No.	Scientific name	Local name	Characteristics
1	*Azolla pinnata*	Azolla	The species is typically triangular measuring about 1.5 to 3.0 cm in length, 1 to 2 cm in breadth. Newly form leaves are green but aged leaves are brown in color. With roots.
2	*Spirodela polyrriza*	Sonapana	Leaves are flat or oval, 6-10.5 mm in length, 5-10 mm wide and 0.6-1.5 mm thick. Deep green above but with deep brown/reddish ventral. It contains 10-15 roots which are 10-40 mm long.
3	*Lemna minor*	Tetulipana	Leaves are flat and elongated, like tamarind tree leaves, 3-4.5 mm in length, 2-2 mm wide and 0.2-0.3 mm thick. Deep green or green in color. It contains single root which is 10-15 mm long.
4	*Wolffia arrhiza*	Sujipana, Dimpana	Leaves are minute and rounded, 0.6-1.2 mm in length and 0.5-1 mm wide. Deep green in color and without roots.

Source: Das (1997)

Azolla pinnata

Spirodela polyrriza

Lemna minor

Wolffia arrhiza

Plate 1.1: Aquatic macrophytes used as feed in weed based aquaculture (Das, 1997)

IIRR-ICLARM (1992) reported some farmers' proven weed based integration to aquaculture farming in different countries like China, Malaysia, Vietnam, Philippines and India. The Indian NGO, Sulabh International conducted two duckweed fish production projects in rural areas of the states of Haryana and Orissa (Iqbal, 1999). Since 1989 the NGO, PRISM- Bangladesh has set up an impressive programme to develop and disseminate duck weed aquaculture in Bangladesh. PRISM has developed three centres located at Mirzapur, Manikgonj and Khulna. The centres served as demonstration farms and training institutions for the promotion of integrated duckweed-fish production in the surrounding villages (DWRP, 1996 and DWRP, 1997).

The aforesaid history clearly indicates the necessity of realizing the efforts made for the development of weed based aquaculture, finding out the lacks in our research system and thereby providing strategy of developing low cost aquaculture technique specially for the resource poor farmers.

1.5.: Efforts made in promoting the weed based aquaculture

Some efforts are already taken to promote the weed based aquaculture (Table 1.4 and Fig. 1.7) in home and abroad.

Table 1.4: Efforts for the promotion of weed based aquaculture.

Efforts taken by	Type of study	Place of Study (Country)	Weed used	Fish species used	Major thrust	Remarks
Talukdar *et al*. (2012)	Experiment	Bangladesh	*Lemna minor*	Tilapia, sharpunti, grass carp, catla, mrigal	Use of weed in fish culture	Economics and nutritional aspects are not explored
Kabir *et al*. (2009)	Experiment	Bangladesh	*Lemna minor*	Tilapia, catla, rui	Fish production performance	Economics and nutritional aspects are not explored
Chowdhury *et al*. (2008)	Experiment	Bangladesh	*Lemna minor*	Nile Tilapia	Use of weed in monoculture	Economics and nutritional aspects are not explored
Ferdoushi *et al*. (2008)	Experiment	Bangladesh	Lemna and Azolla	Sharpunti, catla, mrigal, rui	Water quality	Economics and nutritional aspects are not explored
Abou *et al*. (2007)	Experiment	Benin West Africa	Azolla	Nile Tilapia	Fish growth and economics	Economics and nutritional aspects are not explored
Ansal and Dhawan (2007)	Experiment	India	*Spirodela sp.*	Catla, mrigal, rui	Low-cost carp feed production	Economics and nutritional aspects are not explored
Majhi *et al*. (2006)	Experiment	India	Azolla	Grass carp	Organic fish production	Economics and nutritional aspects are not explored
El-Shafai *et al*. (2004)	Experiment	Egypt	*Lemna* sp.	Nile Tilapia	Use of weed as feed for tilapia culture	Economics and nutritional aspects are not explored
Thy *et al*. (2004)	Experiment	Combodia	Water spinach, duck weed.	Common carp, mrigal	Fish growth	Economics and nutritional aspects are not explored
Azim and Wahab (2003)	Experiment	Bangladesh	*Lemna* sp.	Rui, catla, common carp	Fish growth, pond ecology	Economics and nutritional aspects are not explored
Iqbal (1995)	Pilot project	Bangladesh	*Lemna minor*	Tilapia, rui, catla	Fish growth	Economics and nutritional aspects are not explored
Hassan and Edwards (1992)	Experiment	Vietnam	*Lemna, Spirodella*	Nile Tilapia	Fish growth	Economics and nutritional aspects are not explored
PRISM-Bangladesh (1990)	Pilot project	Bangladesh	*Lemna* sp	Rui, catla, mrigal, silver carp	Use of weed in fish culture	Only one weed is used
Mibagwv and Adeniji (1988)	Experiment	Nigeria	*Lemna sp*	Tilapia	Nutritional value of weed	Only one weed is used

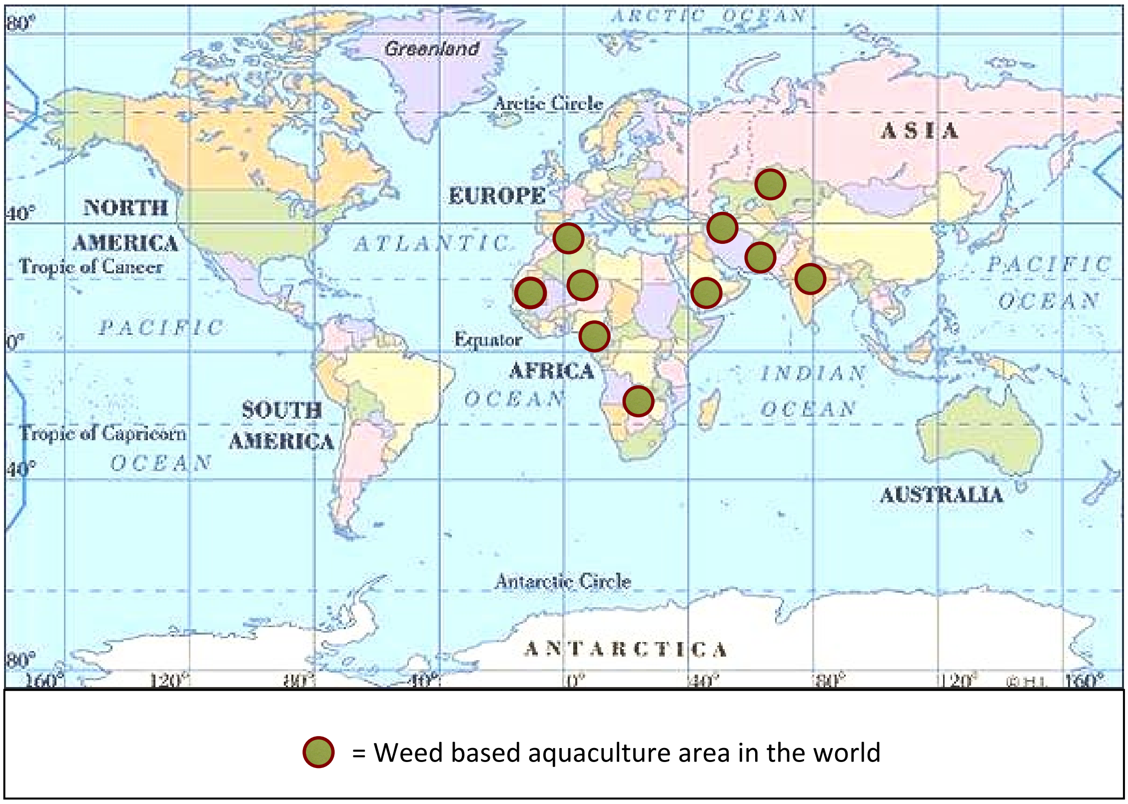


Fig. 1.7. Areas of weed based aquaculture efforts.
{(Source: Talukdar *et al*. (2012), Abou *et al*. (2007), Ansal and Dhawan (2007), Majhi *et al*. (2006)}

Efforts made indicate that

(i) Weeds are used as fish feed at home and abroad.

(ii) Azolla, Lemna, Spirodela and water spinach are used as fish feed for fish farming.

(iii) Fish species- tilapia and Indian major carps are used in weed based aquaculture system.

(iv) Major thrusts are fish production, pond ecology and nutritive value of weed.

(v) Comparative growth performance of fishes using weeds and supplementary feeds (for semi-intensive culture) was not found accordingly in the efforts made in Bangladesh.

(vi) Economics of the weed based system was not explored well in Bangladesh.

(vii) Maximum fish species was not introduced in carp-polyculture system under weed based efforts in Bangladesh.

(viii) Nutritive values of the weeds were also not explored in the efforts made in Bangladesh.

1.6: Research questions

Based on the indications, some questions are also raised:

(i) Can weed based system be considered as a low cost technique as compared to the conventional feed based system?

(ii) Can weed based system be considered as suitable model for a typical carp poly culture including maximum species?

(iii) Which weed performs better than others?

(iv) Which weed is better in terms of maintaining good water quality?

(v) Which weed can be used by most of the species directly or indirectly in polyculture system?

(vi) What is the suitable stocking density of fishes to get higher production for weed based system?

1.7: Research need for weed based aquaculture development in Bangladesh

In recent years, organic aquaculture has been gaining considerable importance. Many farmers have begun shifting from traditional method to organic cultivation as means of producing safe foodstuff and respecting environment. Organic farming favours lower input costs, conserves nonrenewable resources, improves quality of the product and thereby increases farm income. Organic fish farming system rely on biological management in most cases and virtually prohibits utilization of synthetic chemicals in fish production. Earlier efforts are done by using one or two weed species and limited fish species. A technology has little or no value without its economic benefit. In the previous studies, comparative economic analysis of feed and weed system was not found. Nutritive values of the weeds are not also explored well in the study made in Bangladesh.

Based on those arguments, the present study emphasized on determining the nutritional values of weeds and comparing production and economics of fish farming towards the development of low-cost weed based aquaculture technique in Bangladesh.

1.8: Objectives

The general objectives of the present study were as follows:

- to determine the nutritional value of conventional and non-conventional feed items used in carp polyculture;
- to evaluate the growth performance of fishes under different weed and feed based systems;
- to monitor the water quality parameters in ponds under different treatments of weed and feed based systems;
- to evaluate the economics of fish production under different treatments of weed and feed based systems; and
- to recommend suitable weed based technology with suitable stocking density for carp polyculture in ponds.

CHAPTER TWO

REVIEW OF LITERATURE

Review of related literature is a necessity in the sense that it provides as scope for reviewing the stock of knowledge and information relevant to the proposed research. However, the following literatures were reviewed in favour of the present study.

2.1: Nutritive value of weeds and conventional fish feeds

Pullin and Almazan (1983) estimated the nutritive value of Azolla and reported the crude protein, crude lipid, crude fiber, ash and starch as 24-30%, 3-33%, 9.1%, 10.5% and 6.5%, respectively.

Van-Hove and Lopez (1983) reported that Azolla contained 28% crude protein.

Tacon and Jackson (1985) reported that aquatic fern (dry basis) could be used as shrimp and fish feed, as it revealed a good nutritive value in terms of protein 25.3%, crude fat 3.8%, crude fiber 9.3% and ash 12.5%.

Mibagwv and Adeniji (1988) worked with *Lemna* sp. in the Kainji lake, Nigeria and reported crude protein ranging from 26.3-45.5% of dry weight.

Hepher (1988) reported the protein in ricebran, wheat bran, oil cake and Azolla as 11.88%, 14.57%, 30-33% and 19.27%, respectively.

Banerjee and Matai (1990) worked on the nutritive status of *Azolla pinnata* and reported ash as 15.4%, protein as 21.9% and Lipid as 3.8%.

Gavina (1994) reported the percentage composition (dry weight) of Azolla as moisture 5.06%, ash 22.21%, crude protein 20.98%, crude fat 5.17%, crude fiber 19.30%, calcium 1.08% and phosphorous 0.21%.

Suresh and Mandal (2000) worked on the determination of nutritive value of rice bran, mustard oilcake and Azolla. In rice bran they found crude protein and crude fibre as 12.6% and 21.9%, respectively. In mustard oilcake crude protein and crude fibre as 38.6% and 6.8%, respectively and in Azolla crude protein and crude fibre as 26.5% and 20.4%, respectively.

Fasakin and Balogun (2001) made a study on nutritional analysis of *Azolla* sp. and found crude protein as 28.9%, crude fibre as 12.2% and lipid contents as 4.6%. They also noted that nutritive values of *Azolla* sp. were higher than the values of *Spirodela* sp.

El-Shafai *et al*. (2004) reported the protein content of duckweed as 21.1% and wheat bran as 11.0%.

Alalade and Iyayi (2006) conducted an experiment on the chemical composition of Azolla (*Azolla pinnata*) and they reported crude protein, ether extract, crude fibre and ash as 21.4%, 2.7%, 12.7% and 16.2%, respectively.

Abou *et al*. (2007) studied the effects of stocking density on growth and profitability of farming of Nile tilapia (*Oreochromis niloticus*) in Azolla fed ponds and found crude protein, crude fat and crude fibre as 28.51%, 3.97% and 9.60%, respectively in Azolla meal.

Ansal and Dhawan (2007) worked on *Spirodela* sp. for low-cost carp feed formulation and they found crude protein, fat and ash as 30.52%, 1.97% and 9.45%, respectively.

Tavares *et al.* (2008) observed 38.8% crude protein, 3.8% crude fat and 13.2% crude fiber in dried duck weed. They also reported that protein content of duckweeds growing on nutrient poor and nutrient rich water varied between 15-25% and 35-45% (Dry matter basis), respectively.

Ahmed (2011) worked on the use of Azolla as fish feed and found protein, ash, carbohydrate and fat as 20-25%, 10%, 6-6.5% and 3-3.5%, respectively.

Bag *et al*. (2011) worked with aquatic weed as potential feed for Nile tilapia (*Oreochromis niloticus*) and reported as dry matter, organic matter, crude protein, crude lipid, ash and crude fibre as 92.56%, 82.80%, 20.56%, 9.89%, 9.76% and 9.24%, respectively.

2.2: Water quality

Wurts and Durbrow (1992) worked on interactions of pH, carbon dioxide, alkalinity and hardness in fish ponds and they reported the desirable range of pH as 7.5-8.5, CO_2 as 1-2 ppm, alkalinity as 50-150 mg/l and hardness as 75-200 mg/l for pond aquaculture.

Azim *et al*. (1995) recorded mean values of temperature as 26.2°C, transparency as 36.2 cm and pH as 7.1 in fertilized fish pond.

Wahab *et al*. (1995) recorded water temperature from 27.2 to 32.4°C, secchi depth between 26 to 50 cm, pH around 6.0, total hardness from 45 to 108 mg/l and dissolved oxygen from 2.2 to 7.1 mg/l in carp polyculture ponds.

DWRP (1996 and 1997) made a study on weed-based carp polyculture at Tangail and found water temperature, transparency, pH and DO as 28.1 to 32°C, 30 to 35cm, 6.5 to 7.3 and 4 to 6 mg/l, respectively.

Rahman (1999) studied the effect of duckweed on pond ecology and recorded the values of water temperature from 26.2 to 34.5°C, transparency from 12.0 to 46.5 cm, total alkalinity from 71.0 to 175.0 mg/l, pH from 6.5 to 8.8 and dissolved oxygen from 6.0 to 8.0 mg/l.

Dhawan and Kaur (2002a) studied the water quality in polyculture ponds under different treatments of feed utilization (T_1: 0% rice bran + 100% mustard oilcake, T_2: 25% rice bran + 75% mustard oilcake , T_3: 50% rice bran + 50% mustard oilcake, T_4: 75% rice bran + 25% mustard oilcake, T_5: 100% rice bran + 0% mustard oilcake, T_6: 18 L/ha/yr pig dung and T_7: 36 L/ha/yr pig dung) at Punjab, Ludhiana, India. They reported pH in T_1, T_2, T_3, T_4, T_5, T_6 and T_7 as 8.40, 8.36, 8.40, 8.47, 8.56, 8.56 and 8.45, respectively in winter; 8.93, 8.92, 8.94, 8.89, 8.83, 8.93 and 8.55, respectively in summer, DO (mg/l) in T_1, T_2, T_3, T_4, T_5, T_6 and T_7 as 11.41, 11.62, 12.00, 12.11, 12.19, 12.75 and 12.31, respectively in winter; 7.85, 7.60, 7.44, 7.56, 7.57, 7.91 and 7.61, respectively in summer, total alkalinity (mg/l) in T_1, T_2, T_3, T_4, T_5, T_6 and T_7 as 228, 236, 209, 233, 245, 237 and 219, respectively in winter; 310.25, 287.75, 285.50, 319.00, 280.25, 290.50 and 264.75, respectively in summer.

Azim and Wahab (2003) worked on the development of duckweed-fed carp polyculture system in Bangladesh and they stated that the water temperature, transparency, pH, dissolved oxygen and alkalinity ranged from 26°C to 31°C, 29.8 to 35.9 cm, 6.9 to 7.5, 4.1 to 5.25 mg/l and 110.25 to 145.70 mg/l, respectively.

El-Shafai *et al*. (2004) observed the water quality parameters in three different types of treated ponds (sewage-wheat bran fed pond, sewage-duck weed fed pond and freshwater duckweed fed pond). In case of sewage-wheat bran fed pond, values for temperature (°C), pH and DO (mg/l) as 23-35, 8-9.7 and 4.9±4.7, respectively. In case of sewage-duck weed fed pond temperature (°C), pH and DO (mg/l) values were 23-35, 8-9.4 and 5.9±4.7, respectively. In case of freshwater duckweed fed pond temperature (°C), pH and DO (mg/l) values were 23-35, 8.4-9.9 and 5.3±4.1, respectively.

Thy *et al.* (2004) reported the mean values of pH, water transparency (cm) and dissolved oxygen (mg/l) as 8.48, 30.7 and 4.15, respectively in effluent plus duckweed fed pond.

Majhi *et al*. (2006) reported that water temperature, pH, dissolved oxygen and total alkalinity varied from 20-22°C, 7.5-8.2, 7.0-7.8 mg/l and 40 to 45 ppm, respectively in Azolla fed pond.

Rahman *et al*. (2006) observed the water quality parameters in polyculture ponds under 3 treatments of fish stocking densities i.e. T_1 (9,880 nos/ha), T_2 (14,820 nos/ha) and T_3 (19,760 nos/ha). In case of T_1, they reported the mean values of water temperature (°C), transparency (cm), and DO (mg/l) as 29.43, 26.37 and 6.40, respectively. In case of T_2, the mean values of water temperature (°C), transparency (cm), and DO (mg/l) were as 29.36, 23.82 and 6.37, respectively. In case of T_3, the mean values of water temperature (°C), transparency (cm), and DO (mg/l) were as 29.28, 20.71 and 6.29, respectively.

Abou *et al*. (2007) observed the water quality parameters in three different types of treated ponds (30% Azolla fed pond, 35% Azolla fed pond and 40% Azolla fed pond). In case of 30% Azolla fed pond, transparency (cm), temperature (°C), pH, DO (mg/l), nitrates (mg/l), nitrites (mg/l), and ammonium (mg/l) values were 42.2±8.8, 28.8±0.2, 6.61±0.11, 4.48±0.24, 0.12±0.01, 0.01±0.00 and 0.46±0.07, respectively. In case of 35% Azolla fed pond, transparency (cm), temperature (°C), pH, DO (mg/l), nitrates (mg/l), nitrites (mg/l), and ammonium (mg/l) values were 40.4±7.2, 28.9±0.1, 6.40±0.29, 4.66±0.26, 0.10±0.02, 0.01±0.00 and 0.42±0.01, respectively. In case of 40% Azolla fed pond, transparency (cm), temperature (°C), pH, DO (mg/l), nitrates (mg/l), nitrites (mg/l), and ammonium (mg/l) values were 45.1±2.1, 29.0±0.1, 6.46±0.20, 4.44±0.10, 0.11±0.02, 0.01±0.00 and 0.48±0.07, respectively.

Chowdhury *et al*. (2008) conducted an experiment on monoculture of Nile tilapia with duckweed (*Lemna minor*) as supplementary feed for a period of 90 days under 2 treatments viz. T_1 (Duckweed fed pond) and T_2 (without duckweed). In case of treatment T_1, they stated the water temperature (°C), transparency (cm), DO (mg/l), pH, free CO_2 (mg/l) and alkalinity (mg/l) were 28.30, 28.66, 7.64, 7.53 and 59.75, respectively. In case of treatment T_2, they stated the water temperature (°C), transparency (cm), DO (mg/l), pH, free CO_2 (mg/l) and alkalinity (mg/l) were 28.59, 34.50, 7.29, 7.58 and 64.58, respectively.

Ferdoushi *et al*. (2008) studied the effects of two aquatic floating macrophytes (Lemna and Azolla) as biofilters of nitrogen and phosphate in fish ponds under three treatments T_1 (Lemna fed pond), T_2 (Azolla fed pond) and T_3 (without any macrophytes). In case of Lemna fed pond, temperature (°C), transparency (cm), dissolved oxygen (mg/l), pH, alkalinity (mg/l), NO_3-N (mg/l) and PO_4-P (mg/l) were found as 29.60±2.97, 34.69±11.93, 4.80±1.93, 7.53b±0.034, 133.87±18.95, 1.29±0.39 and 1.04±0.75, respectively. In case of Azolla fed pond, temperature (°C), transparency (cm), dissolved oxygen (mg/l), pH, alkalinity (mg/l), NO_3-N (mg/l) and PO_4-P (mg/l) were found as 29.30±2.63, 36.32±19.16, 4.84±1.63, 7.61±0.39, 144.93±25.09, 1.33±0.40 and 1.04±0.76, respectively. In case of control pond, temperature (°C), transparency (cm), dissolved oxygen (mg/l), pH, alkalinity (mg/l), NO_3-N (mg/l) and PO_4-P (mg/l) were found as 29.57±2.59, 26.27±13.47, 5.27±1.86, 8.09±0.46, 224.41±47.36, 1.87±0.63 and 1.64±1.02, respectively.

Bag *et al*. (2011) reported the mean values of water temperature, pH, free CO_2 and DO as 30°C, 7.2, 0.5 mg/l and 6 mg/l, respectively in ponds under aquatic weed based tilapia farming in India.

Talukdar *et al*. (2012) worked on the suitability of duckweed (*Lemna minor*) as feed for fish in polyculture system under two treatments i.e. T_1 (*Lemna minor* fed pond) and T_2 (without *Lemna minor*). In case of treatment T_1, they reported water temperature (°C), transparency (cm), DO (mg/l), pH, free CO_2 (mg/l) and alkalinity (mg/l) were 28.02, 30.50, 6.63, 7.45, 2.85 and 75.33, respectively. In case of treatment T_2, water temperature (°C), transparency (cm), DO (mg/l), pH, free CO_2 (mg/l) and alkalinity (mg/l) were 27.92, 32.08, 6.23, 7.43, 2.90 and 74.00, respectively.

2.3: Fish production

Gaiger *et al.* (1984) studied the production of tilapia in three different types of ponds (only duckweed fed pond, only pellete fed pond and duckweed + pellete fed pond). They reported a good feed conversion ratio (1:1) and poor growth rate (0.67% of body mass d^{-1}) in ponds fed with only duckweed. When the fish were fed pellets in addition to duckweed the rate of duckweed consumption decreased and growth rate of the fish doubled with feed conversion ratios between 1.2 and 1.8. Fish grown on the mixed diet performed similarly to fish grown on pellets but had a better feed conversion ratio.

Edwards (1990) conducted an experiment on the use of terrestrial vegetation and aquatic macrophytes in aquaculture and reported tilapia yield of 3.7 t/ha/year from the fertilization of the water with excreta and 13.4 t/ha/year with the addition of Azolla as a nutritional supplement.

Shanmugasundaram and Balusamy (1993) reported the use of Azolla as feed to raise Indian major carps (catla: rohu: mrigal = 1:1:1) in low-lying wetlands with a stocking density of 3000/ha and thereby found the fish yield as 154 kg/ha.

Skillicorn *et al.* (1993) stated that the average yield of fish per hectare was estimated at around 10 tons annually using only duckweed as the supplement to the naturally available fish feed.

Gavina (1994) worked on pig-duck-fish-Azolla integration under 3 treatments i.e., T_1 (commercial feed alone), T_2 (fresh Azolla+60% commercial feed), T_3 (fresh Azolla+40% commercial feed) with a same stocking density (20,000 no/ha) for all the treatments and reported the fish production after four months of culture period, were 581, 436 and 374 kg/ha in treatment T_1, T_2 and T_3, respectively

Ahmed *et al.* (1995) studied the impact of improved aquaculture technologies in ponds fed with duckweed. They reported the carp production as 11.04 kg/40 m^2, silver barb production as 6.75 kg/40 m^2 and Nile tilapia production as 13.43 kg/40m^2 with a stocking density of 25-30, 60-65 and 80-85/40m^2 for carp, Silver barb and Nile tilapia respectively.

Gopakumar *et al.* (1999) reported the fish production as 3-4 tonnes/ha/year in ponds under weed based carp polyculture in India.

Grover *et al.* (2000) recommended the Azolla based carp polyculture in ponds with a stocking density of 9880 nos/ha (catla : silver carp : grass carp : rajpunti : mrigal : kalbaus : common carp = 4:6:3:8:10:3:3:3) and thereby made assumption of fish production as 5575 kg/ha.

Cagauan *et al*. (2000) studied the growth of Nile tilapia (initial stocking size of 10-20 g) stocked at a density of 10,000 fishes/ha in integrated fish and Azolla farming pond in Philippines and observed the fish production as 3381.75 kg/ha/yr.

Abdelghany and Ahmad (2002) studied the growth and production of fish (Nile tilapia, common carp and silver carp) in Azolla fed pond for a period of 19 weeks under five different treatments. Feeding dose were 0.0% (T_1), 0.5% (T_2), 1.0% (T_3), 3.0% (T_4), 5.0% (T_5) fish biomass per day and apparent satiation (T_6). Each pond was stocked with 1000 Nile tilapia, 1000 silver carp and 200 common carp with average initial weights of 13.7g, 1.9g and 10.9g, respectively. Fish yield (kg/ha) was 2770, 3226, 3571, 4598, 4225 and 4637 with treatment T_1, T_2, T_3, T_4, T_5 and T_6, respectively,

Dhawan and Kaur (2002b) evaluated the fish growth in pig dung treated polyculture pond during winter and summer and reported that the growth of Indian major carps viz *Catla catla*, *Labeo rohita* and *Cirrhina mrigala* was higher during summer and that of exotic carps viz *Cyprinus carpio* and *Ctenophayrengodon idella* was higher during winter.

Jena *et al*. (2002a) conducted another experiment to evaluate the fish production performance under 3 treatments of polyculture stocked with six carp species, viz., catla, rohu, mrigal, silver carp, grass carp and common carp in the ratio of 2:2:2:2:0.5:1.5, at a combined density of 10,000 fingerlings/ha with average stocking weight of 17.5 g. The treatments were T_1 (single cropping-the fishes were harvested after rearing period of one year), T_2 (single stocking and multiple harvesting- the fishes of larger size were harvested at monthly intervals from the seventh month onwards) and T_3 (multiple cropping system-the fishes were harvested only after a rearing period of 6 months as first crop, which was restocked again after due pond preparation for second crop of 5.5 months). The net production recorded in treatments T_1, T_2 and T_3 were 5843.8 kg/ha/year, 6320.3 kg/ha/year and 6828.4 kg/ha/year, respectively.

Jena *et al*. (2002b) evaluated the production performance of carps under 4 treatments i.e. T_1 (5000 fingerlings/ha with six carp species: catla, rohu, mrigal, silver cap, grass carp and common carp, in the ratio of 2 : 2.5 : 2.0 : 1.5 : 0.5 : 1.5), T_2 (5000 fingerlings/ha with three Indian major carp species: catla, rohu, mrigal, in the ratio of 3 : 4 : 3), T_3 (10000 fingerlings/ha with six carp species: catla, rohu, mrigal, silver cap, grass carp and common carp, in the ratio of 2 : 2.5 : 2.0 : 1.5 : 0.5 : 1.5) and T_4 (10000 fingerlings/ha with three Indian major carp species: catla, rohu, mrigal, in the ratio of 3 : 4 : 3). The mean initial stocking sizes of catla, rohu, mrigal, silver carp, grass carp and common carp were 15 g, 5 g, 4 g, 9 g, 33 g and 8 g, respectively. They reported mean net production levels in T_1, T_2, T_3 and T_4 as 1791 kg/ha, 2385 kg/ha, 2532 kg/ha and 3472 kg/ha, respectively in 6 months.

Azim and Wahab (2003) studied the effects of duckweed (*Lemma* sp) application on fish production. They reported that a stocking density of Thai silver barb at the rate of 6000 fingerlings ha^{-1} with 3300 rohu, 3300 catla and 3400 common carp fingerlings ha^{-1} was found appropriate species mix for duckweed fed poly culture system and the net fish production was 2020 kg ha^{-1} during a 4-month culture period.

El-Shafai *et al*. (2004) recommended that fresh duck weed is superior to wheat bran as supplementary feed in tilapia pond farming. In their experiment the stocking density was 50 fish/dec (initial stocking weight of 20g) per pond under continuous aeration and regular removal of feaces for a period of 150 days and feeding rate was 25 g fresh Azolla/100g fish. They reported that duckweed fed ponds provided higher net fish yield (11.8 ton/ha/y) than that of wheat bran fed ponds (8.9 ton/ha/y).

Thy *et al.* (2004) worked on the effect of water spinach and duckweed on fish growth in poly culture ponds in Cambodia under 3 treatments i.e. T_1 (Effluent), T_2 (Effluent + water spinach) and T_3 (Effluent + duckweed) stocked with three fish species at a density of 3 fishes per m^2 with the species tilapia (*Oreochromis niloticus*), common carp and mrigal (*Cirrhinus mrigala*) with a composition of 40%, 35% and 25%, respectively. The water spinach and duckweed were supplied daily at 3 to 5% (Dry matter basis) of fish bodyweight. They reported the survival rate, daily weight gain and total yield as 88.3%, 6.17 kg/ha/day and 1,450 kg/ha/4 months for common carp, 90.6%, 15.2 kg/ha/day and 2,470 kg/ha/4 months for mrigal and 92.4%, 21.2 kg/ha/day and 3,120 kg/ha/ 4 months for tilapia, respectively.

Rahman *et al*. (2006) conducted an experiment on the culture potential of Thai sharpunti with major carps in seasonal ponds for a period of 90 days under 3 treatments i.e. T_1 (stocking density of rohu, catla, mrigal, silver carp and Thai sharpunti fingerlings was 494, 494, 1,482, 1,235 and 9,880/ha, respectively), T_2 (stocking density of rohu, catla, mrigal, silver carp and Thai sharpunti fingerlings was 494, 494, 1,482, 1,235 and 14,820/ha, respectively) and T_3 (stocking density of rohu, catla, mrigal, silver carp and Thai sharpunti fingerlings was 494, 494, 1,482, 1,235 and 19,760/ha, respectively). All the fishes were fed with supplementary diet comprising of rice bran and mustard oil cake (1:1) at the rate of 6-7% of the estimated body weight twice daily. They found the total fish production as 1,248.34, 1,343.19 and 1,592.67 kg/ha in treatment T_1, T_2 and T_3, respectively.

Majhi *et al*. (2006) worked on the effect of Azolla feeding on growth performance of grass carp under 2 treatments i.e T_1 (Azolla fed pond) and T_2 (Control) with the stocking density of 0.75 fish/m^2 in each pond for a period of 150 days. The fish were fed everyday at 9.30 am at the rate of 10% of fish biomass. They found growth of grass carp fed with T_1 (Azolla fed pond) was remarkably high (1.65 g/fish/day) and the total production of fish was 1850.76 kg/ha.

Abou *et al*. (2007) conducted an experiment to observe the effect of stocking density on growth, yield and profitability of farming Nile tilapia fed with Azolla diet in earthen ponds under 3 treatments i.e. T_1 (30% Azolla), T_2 (35% Azolla) and T_3 (40% Azolla) for a period of 90 days with a stocking density of 1 fish/m^2 for all the treatments. They reported the fish production (kg/acre/y) as 70.75±1.48, 67.95±0.71 and 65.01±2.21 in T_1, T_2 and T_3, respectively.

Chowdhury *et al*. (2008) conducted an experiment on monoculture of Nile tilapia with duckweed (*Lemna minor*) as supplementary feed for a period of 90 days under 2 treatments viz. T_1 (Duckweed fed pond) and T_2 (Control) stocked with 80 fingerlings/dec. They reported the mean survival rate (%), SGR (%, bwd^{-1}), net production (kg/ha/yr) as 94.37 and 93.75, 1.16 and 0.80, 4021.16 and 2203.24 in treatment T_1 and T_2, respectively.

Ferdoushi *et al*. (2008) conducted an experiment on the effects of two aquatic floating macrophytes (Lemna and Azolla) as biofilters of nitrogen and phosphate in fish ponds for a period of four months under 3 treatments i.e. T_1 (Lemna fed pond), T_2 (Azolla fed pond) and T_3 (Control) with the similar stocking densities in all treatments. The stocking densities were three native carps: *Labeo rohita*, *Cirrhina mrigala*, *Catla catla* and one exotic carp, Thai sharpunti (*Barbonymus gonionotus*) were 2,000, 2,000, 2,000 and 5,000/ha, respectively. Lemna and Azolla were periodically supplied at the rate of 4% of body weight of Thai sharpunti (*B. gonionotus*) and made available for 24 hours, per day. Commonly available ingredients such as rice bran and mustard oil cake were also used as supplementary feed daily at the rate 4% of body weight of total fish in all the treatments. They reported that these two macrophytes increase fish production.

Bag *et al*. (2011) worked on making Azolla as potential feed for Nile tilapia under 4 treatments i.e. T_1 (Lemna meal), T_2 (Water hyacinth meal), T_3 (Azolla meal) and T_4 (Control) for a period of 90 days with the stocking density of 260 Nile tilapia/dec (average weight of 5.5 g and length of 4.5 cm). They reported the final weight as 80.66±0.73 g and final length as 12.9±0.14 cm and feed intake as 2.01±0.20 g Azolla/fish/day.

Talukdar *et al*. (2012) worked on the suitability of duckweed (*Lemna minor*) as feed for fish in polyculture system under two treatments i.e. T_1 (*Lemna minor* fed pond) and T_2 (without *Lemna minor*) with the stocking density of 40 fishes/40 m^2 (tilapia : sharpunti : grass carp : catla : mirgal = 45:38:15:38:15). They reported the survival rate (%) of tilapia, sharpunti, grass carp, catla and mrigal as 82, 88, 96, 82, 95 with treatment T_1 and 82, 88, 86, 90, 96 with treatment T_2. They mentioned the initial weight (g) of tilapia, sharpunti, grass carp, catla and mrigal as 32.67, 30.33, 74.33, 28.47, 18.83 with treatment T_1 and 32.67, 30.33, 74.33, 28.47, 18.83 with treatment T_2 and the end of the experiment they reported the final weight (g) of tilapia, sharpunti, grass carp, catla and mrigal as 68.92, 65.67, 231.03, 26.82, 84.69 with treatment T_1 and 53.11, 56.72, 115.38, 28.40, 74.00 with treatment T_2.

2.4: Economics

Shanmugasundaram and Balusamy (1993) worked on rice-fish-Azolla integration in India. They stocked 3 Indian major carps (catla : rohu : mrigal = 1 : 1 : 1) at a stocking density of 3000 nos/ha. Azolla was applied twice a day at 2 tonnes/ha. Banana pseudostem, cowdung and rice bran were supplied as supplementary feed at 5% bwd^{-1}. They stated that gross return ((US$/ha) was 985, net return (US$/ha) was 463 and benefit cost ratio was 1.88.

Ahmed *et al*. (1995) made a comparative study on economics of carp, silver barb and tilapia faming and reported that average net income of carp farmers was almost triple (2.92 times) than that of silver barb farmers, and more than double (2.12 times) than that of Nile tilapia farmers. They also reported that cost of production in silver barb culture was 34% higher than carp polyculture, and 32% higher than Nile tilapia culture.

Abdelghany and Ahmad (2002) worked on the effects of feeding rates on growth and production of Nile tilapia, common carp and silver carp reared in polyculture system under 6 treatments i.e. 0.0% (T_1), 0.5% (T_2), 1.0% (T_3), 3.0% (T_4), 5.0% (T_5) and apparent satiation (T_6). Total cost (US$/ha) was 628.07, 1064.67, 1461.51, 2759, 5180.51 and 2520.31 in treatments T_1, T_2, T_3, T_4, T_5 and T_6, respectively. Income from fish sale (US$/ha) was 3968.26, 4738.54, 5157.93, 6986.33, 6365.42, 7064.37 in treatments T_1, T_2, T_3, T_4, T_5 and T_6, respectively. Net profit (US$/ha) was 3340.19, 3673.87, 3696.42, 4226.85, 1184.91 and 4544.06 in treatments T_1, T_2, T_3, T_4, T_5 and T_6, respectively.

Roy *et al*. (2003) studied economics of carp-SIS polyculture and their economic analysis under 3 treatments i.e. T_1 (only carps), T_2 (carps with mola) and T_3 (carps with chela) in which the stocking density of Indian major carps, rohu (*Labeo rohita*), catla (*Catla catla*) and mirgal (*Cirrhinus mrigala*) was 9,500 fish/ha with a ratio of 1:1:1, respectively, grass carp (*Ctenopharyngodon idella*) 500 fish/ha, mola (*Amblypharyngodon mola*) and chela (*Chela cachius*) 25,000 fish/ha. They reported the total operational cost as 32,450.00, 39,950.00 and 42,450.00 Tk./ha/7 months in treatments T_1, T_2 and T_3, respectively. The total revenue was 128,000.00, 128,280.00 and 110,720.00 Tk./ha/7 months in treatments T_1, T_2, and T_3, respectively. Benefit-cost ratio (BCR) was obtained as 3.94, 3.21 and 2.61 in treatments T_1, T_2 and T_3, respectively. BCR was higher in only carp polyculture system because the operational cost was comparatively lower due to the absence of small fish.

Majhi *et al*. (2006) studied the economic evaluation of grass carp production with Azolla feeding and they reported the net profit of \$118.00 (\$0.12/m^2) was obtained from 1000 m^2 pond with an investment of \$314.

Abou *et al*. (2007) conducted an experiment on cost, returns and profitability of feeding Nile tilapia under 3 treatments i.e. T_1 (30% Azolla), T_2 (35% Azolla) and T_3 (40% Azolla) for a period of 90 days. They reported investment cost (US\$) as 37.5, 36.8 and 36.6, gross return (US\$) as 85.7, 82.8 and 79.0, net return (US\$) as 48.2, 46.0 and 43.4 and profitability (%) as 1.3, 1.3 and 1.2 with treatments T_1, T_2 and T_3, respectively.

Ebrahim *et al*. (2007) worked on the economical analysis of the different levels of Azolla meal on Nile tilapia fingerlings under 5 treatments i.e. T_1 (0% Azolla meal), T_2 (10.6% Azolla meal), T_3 (21.2% Azolla meal), T_4 (31.8% Azolla meal) and T_5 (42.4% Azolla meal). They found the return IE (Egyptian pound) as 2.24, 1.90, 2.43, 2.17, 1.30 in treatments T_1, T_2, T_3, T_4 and T_5, respectively. They mentioned that the treatment T_3 got highest benefit among the treatments.

Khan *et al*. (2009) conducted an experiment of the economics of pangasiid catfish (*Pangasius hypophthalamus*) and silver carp (*Hypophthalmichthys molitrix*) polyculture under 3 treatments of feeding frequencies i.e. T_1 (feeding once a day), T_2 (feeding two times a day) and T_3 (feeding three times a day) with the stocking density of 25,000 fishes/ha. They reported that the treatment T_3 having generated the maximum benefit as compared to others.

CHAPTER THREE

Determination of protein, lipid and carbohydrate contents of conventional and non-conventional feed items used in carp polyculture pond

3.1: Introduction

The technique of polyculture of fish is based on the concept of utilization of different trophic and spatial niches of a pond in order to obtain maximum fish production per unit area. Different compatible species of fish of different trophic and spatial niches are raised together in the same pond to utilize all sorts of natural food available in the pond (Rahman *et al*., 1992). Since the idea of polyculture is based on the principle that each species stocked has its own feeding niche that does not completely overlap with the feeding niches of other species therefore, a more comprehensive use is made of the food resources and space available in polyculture than in monoculture. In South Asia, especially in Bangladesh, several culture combinations of indigenous and exotic carp species are commonly practiced (Wahab *et al*., 1994; Miah *et al*., 1997). In some cases, one species enhances the food availability for other species and thus increases the total fish yield per unit area (Hepher *et al*., 1989; Miah *et al*., 1993; Azad *et al*., 2004).

Growth and reproduction of fish and other aquatic animals are primarily dependent upon an adequate supply of nutrient, both in terms of quantity and quality, irrespective of the culture system in which they are grown. Supply of inputs (feeds, fertilizers etc.) has to be ensured so that the nutrients and energy requirements of the species under cultivation are met and the production goals of the system are achieved. Complete data on nutrient requirements are only available for a limited number of species. Although, dietary proteins. lipids and carbohydrates utilization is relatively well investigated for several fishes, available data on nutrient requirements for carp species are presented in table 3.1.

Table 3.1: Dietary protein requirement for highest growth rate of fishes in carp polyculture

Carp species	Crude dietary protein (%)
Common carp (*Cyprinus carpio*)	31-40.6
Rohu (*Labeo rohita*)	34-36
Grass carp (*Ctenopharyngodon idella*)	23-28
Silver carp (*Hypophthalmichthys molitrix*)	22-29
Catla (*Catla catla*)	24-27
Mrigal (*Cirrhinus cirrhosus*)	22-28
Thai punti (*Barbonymus gonionotus*)	20-25

Source: Hepher (1990), Tacon (1990), De Silva and Anderson (1995) and Hasan *et al*. (1996).

Supplementary feed plays an important role in achieving higher fish production. Unfortunately lack of low cost supplementary feed is found as one of the major problems in aquaculture in Bangladesh (DoF, 2011). Conventional supplementary feed for carps comprises rice bran, wheat bran and oil cakes (Table 3.2). Although rice bran and mustard oil cake are being used as supplementary fish feed in Bangladesh, these materials are costly. Fish meal and other animal byproducts, as source of protein, are not available for use in fish feeds. Commercial fish feeds are not easily available and unaffordable to poor fish farmers in Bangladesh. Consequently, there is no regular organized supplementary feeding practice and the fish production is found as low as 0.5-1.5 t/ha/year (Suresh and Mandal, 2000). It was thus considered necessary to look for cheaper and locally available materials as substitutes.

The optimal protein requirements of carp are affected by the nutritional value of the dietary protein and level of non-protein energy in the carp diet. When sufficient energy sources such as lipids and carbohydrates are available in the diet, most of the ingested protein goes to protein synthesis. Adult Indian major carps require 30% dietary protein for proper growth and survival. Lipids or fats are required as sources of energy and essential fatty acids, and serve as carriers for fat-soluble vitamins. The gross lipid requirement of Indian major carp is 7-8% of the diet, and young fish require relatively more fat and protein than adults. Carbohydrate is the least-expensive nutrient and also a less expensive energy source for carp. Indian major carp, being herbivorous/ omnivorous feeders, easily digest appreciable quantities of carbohydrates in their diets. A dietary level up to 30% carbohydrate does not affect the growth of carp and growth retardation and reduced feed efficiency are observed, however, when carbohydrate levels exceeded 35% of diet (Murthy, 2003).

Table 3.2: Nutritional status of major conventional feed items used in carp polyculture in Bangladesh

Feed items	Crude protein (%)	Crude lipid (%)	Crude fibre (%)
Rice bran	12.6	16.5	16.3
Wheat bran	18.2	4.4	14.0
Mustard oilcake	36.5	11.2	11.6
Coconut oilcake	18.2	10.2	11.7
Fishmeal	56.4	19.7	2.2
Blood meal	92.9	0.3	0.5
Bone meal	17.5	5.2	3.5
Soybean meal	45.2	20.5	5.0

Source: Hasan *et al*. (1989); Hasan *et al*. (1994); Zaher and Mazid (1994); Hossain (1996)

Fish culture is induced primarily by the need for increased protein supply. One of the most essential prerequisites for the successful management of fish culture programme is a comprehensive understanding of feeding (Halver, 1972). The increase in cost and demand of feed protein from conventional sources necessitates fish culturists of the developing countries to incorporate cheap and locally available ingredients in fish feeds. Recently the utilization of aquatic plants having high food value are used to supplement fish food has taken a new dimension for producing the much required animal protein at low cost (Lakshmanan *et al*., 1967).

Aquatic macrophytes have been known to have potential food value (Edwards, 1980). A perusal of the available literature shows that some of the aquatic weeds are highly nutritive and, therefore, one alternative solution to check the massive population of these weeds might be their utilization through incorporation as components of feedstuff for fish. In fact, significant effort has been directed towards evaluating the nutritive value (Table 3.3) of different non-conventional feed resources, including terrestrial and aquatic macrophytes, to formulate nutritionally balanced and cost-effective diets for fish and poultry (Edwards *et al*., 1985; Patra and Ray, 1988; Ray and Das, 1995; Wee and Wang, 1987). Most of these nutritional studies are carried out abroad and no comprehensive studies are found in comparing the nutritional quality of both conventional and non-conventional feeds for fish farming in Bangladesh. However, before advocating the utilization of these aquatic weeds for supplementation of fish feeds, there is an urgent need to explore their nutritional quality, throughout the major culture season in ponds under carp polyculture system. Therefore, the present study aimed at evaluating the protein, lipid and carbohydrate content in conventional and non-conventional feed items used for carp polyculture system in Bangladesh.

Table 3.3: Nutritive status of non-conventional feed items.

Species	Protein (%)	Lipid (%)	Carbohydrate (%)
Azolla pinnata	21.9	3.8	-
Chara sp.	17.5	1.63	23.0
Eichhornia crassipes	16.5	3.4	28.1
Ipomoea aquatica	20.6	4.6	-
Lemna minor	20.4	3.8	-
Nymphae spp.	16.4	2.6	-
Trapa natans	10.8	5.1	-
Wolffia arrhiza	21.5	5.50	10.6
Banana leaves	6.0	-	-
Cassava leaves	2.0	-	-
Sweet potato leaves	2.0	-	-

Source: Boyd (1968, 1969), Culley and Epps (1973), Banerjee and Matai (1990) and Boeck (1996)

3.2: Specific objectives

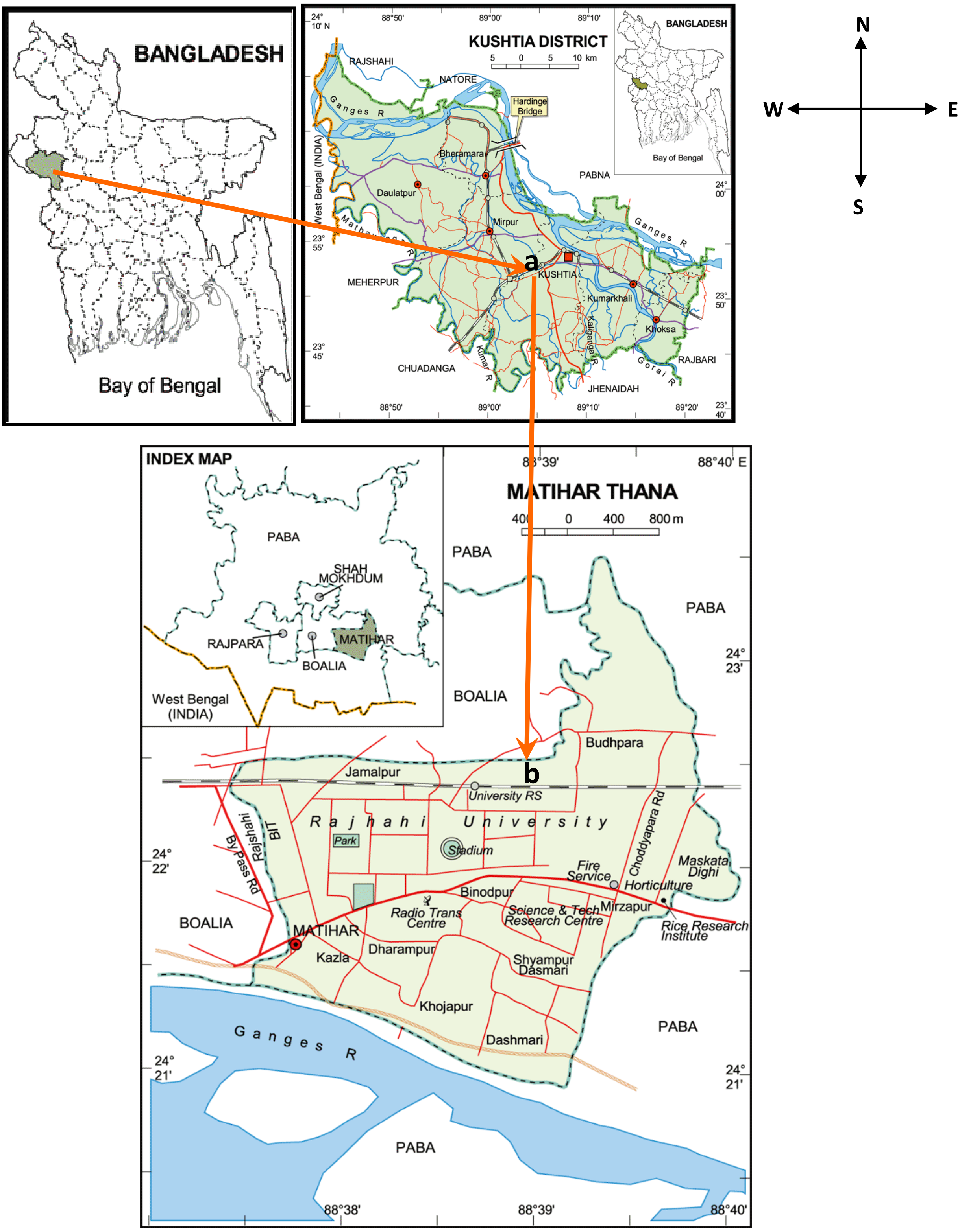
The specific objectives included in this study were as follows-

- to compare the protein, lipid and carbohydrate contents in feed items (rice bran, wheat bran, oilcake, Azolla, grass and banana leaves); and
- to recommend suitable strategy in selecting feed item for the development of weed based fish farming in carp polyculture pond.

3.3: Materials and methods

3.3.1: Duration and location of the study

The study was conducted for a period of six months from April 2010 to September 2010. Feed items were collected from the fish farming study site located at Alampur village under Kushtia district of Bangladesh (Map 3.1). Whereas nutrient analysis was done at the Protein and Enzyme Research Laboratory under the Department of Bio-Chemistry and Molecular Biology, Rajshahi University, Rajshahi, Bangladesh.



Map 3.1: Study site (a: site for feed item collection and b: site for feed analysis)

3.3.2: Experimental design

The current experiment was carried out under six treatments of feed items each with three replications. The treatment assignments were designated as T_1, T_2, T_3, T_4, T_5 and T_6 for rice bran, wheat bran, mustard oilcake, Azolla, grass and banana leaves, respectively.

Conventional feed items (rice bran, wheat bran, mustard oilcake) were collected from local market during the experimental period. Non-conventional feed item like Azolla was collected from Azolla ponds adjacent to the research area whereas grass and banana leaf were collected from adjacent grass field and banana garden. Both conventional and non-conventional feed items were collected once a month for nutritional analysis during the experimental period.

3.3.3: Nutrient analysis of the collected samples

Determination of total protein content

Total protein contents of samples were determined by the micro-kjeldahl method (Rangama, 1979).

Apparatus required

Kjeldahl digestion flask: (250 ml capacity), Distillation apparatus, 100 ml conical flask, 50 ml beaker, 50 ml burette and 100 ml volumetric flask.

Reagents required

a) **Mixed indicator:** Prepared 0.1% bromocresol green and 0.1% methyl red indicators in 95% alcohol separately. 10 ml of the bromocresol green was mixed with 2 ml of the methyl red solution in a bottle provided with a dropper, which delivered 0.05 ml per 4 drops.

b) **2% Boric acid:** 10 g of boric acid (crystals) was dissolved in 500 ml of boiling distilled water. After cooling, the solution was transferred into a glass-stoppered bottle.

c) **30% Sodium hydroxide solution:** 150 g of sodium hydroxide pellets was dissolved in 375 ml of distilled water. The solution was stored in a bottle closed with rubber stopper.

d) **Catalysts for digestion:** 2.5 g of powdered selenium dioxide (SeO_2), 100 g of potassium sulphate (K_2SO_4) and 20 g of copper sulphate ($CuSO_4$, $5H_2O$) were mixed.

e) **0.01 N Hydrochloric acid:** The concentration of the solution was checked against pure sodium carbonate.

Procedure

Digestion

The samples were weighed accurately and transferred to a 250 ml Kjeldahl flask. 1 g of catalyst mixture and 25 ml of conc. H_2SO_4 were added to it. The flask was placed in an inclined position on the stand in the digestion chamber. The flask was heated gently over a low flame until the initial frothing was ceased and the mixture was boiled briskly at a moderate rate. During heating the flask was rotated several times. The heating was continued until the color of the digest was pale blue. The digest was cooled and 30 ml of water was added to 5 ml portion with mixing. The digest was transferred to a 100 ml volumetric flask. The flask was then rinsed 3 times with water and the washings were transferred to the volumetric flask. The solution was made up to volume with water. A blank digestion was carried out without the sample and the digest was made up to 100 ml in total.

Distillation and titration

The distillation apparatus was placed under the condenser. The distilled water was boiled in the steam generator using a Bunsen burner. Stop crock and pink clamp were closed. Cold water was run through the condenser, from which 5 ml of distillate was collected per minute. The burner was removed, where upon the condensate in the distilling flask was sucked back into the steam trap. Funnel was filled with distilled water, and the stopcock was opened momentarily to drain the water into flask.

The burner was then replaced under the steam generator for about 20 seconds and it was removed again. 20 ml of 2% boric acid was pipetted into a clean conical flask and the mixed indicator was added to it. The micro burette was filled with 0.01 N HCl to the zero mark by this time; the distilling flask had become empty. The burner was replaced under the steam generator and pinch clamp was opened to remove liquid from the steam trap. The pinch clamp was left on the glass tubing through which the steam was escaped. The beaker was replaced under the condenser with the conical flask containing boric acid, and the flask was supported in an oblique position, so that the tip of the condenser was completely immersed into the liquid. The stopcock was opened with one hand and with the other hand 10 ml of the digest was pipetted. The funnel was rinsed twice with 3 ml portions of distilled water. Then necessary amount of 30% NaOH was introduced and stopcock was closed. The pinck cock was replaced on the digestion mixture and sodium hydroxide, and the ammonia was liberated which escaped with steam through the condenser into the boric acid solution.

The boric acid was changed from bluish purple to bluish green as soon as it came in contact with ammonia. The change, which was very sharp, was taken place between 20 to 30 seconds after the pinch clamp was closed. Boric acid had changed color within 5 minutes; the conical flask was lowered sot that the condenser tip was 1 cm above the liquid. The end of the condenser was washed with a little distilled water. Distillation was continued until sufficient distillate was collected. The burner was then removed. The distillate was titrated with standard hydrochloric acid until the blue color was disappeared. The titrated was done in daylight. The blank distillation and titration were carried out as in the case of the sample. The percentage of protein in sample was calculated using the following formula:

$$\text{Percentage of nitrogen} = \frac{(V_A - V_B) \times N \times 14 \times V_M \times 100}{A \times W \times 100}$$

Where,

W = Weight of the sample taken

V_A = Volume of HCl in actual titration

V_B = Volume of HCl in blank titration

N = Normality of HCl

V_M = Volume made up of the digest

A = Aliquot of the digest taken

Thus, % Protein = % Nitrogen $\times$ 6.25

Determination of lipid content

Lipid content of the samples were determined by Bligh and Dyer (1989) method.

Reagent used

A mixture of chloroform and ethanol (2:1V/V).

Procedure

5 g of sample were first grinded in a morter and pasted with 10 ml of distilled water. The grinded sample was transferred to a separating funnel and 30 ml of chloroform-ethanol mixture was added. The mixture was mixed well. It was then kept overnight at room temperature in the dark. At the end of this period 20 ml of chloroform and 20 ml of water were further added and mixed. Generally three layers were seen. A clear lower layer of chloroform containing the entire lipid, a colored aqueous layer of ethanol with all water soluble materials and a thick pasty inter phase were seen.

The chloroform layer was carefully colleted in a pre-weighed beaker (50 ml) and then placed on a steam bath for evaporation. After evaporation of the chloroform, the weight of the beaker was determined again. The difference in weight gives the amount of the lipid.

Calculation

Percent of lipid content (g per 100 g of sample) = $\frac{\text{Amount of lipid obtained}}{\text{Weight of sample}} \times 100$

Determination of carbohydrate content

The starch content of samples were determined by the Anthrone method (Boel *et al*. 1988)

Reagents used

Anthrone regent (0.2% in concentrated H_2SO_4), standard starch solution (10 mg / 100 ml distilled water) and 1(M) HCl

Procedure

5 g of samples were homogenized well with 10 ml of water. It was then filtered through double layer of muslin cloth. To filtrate twice the volume of ethanol was added to precipitate the polysaccharide, mainly starch. After kept it over night in cold the precipitate was collected by centrifugation in a clinical centrifuge at 3000 r.p.m. for 15 minutes. The precipitate was then dried over a steam bath. Then 40 ml of 1 (M) hydrochloric acid was added to the dried precipitate and heated to 70°C. It was then transferred to a volumetric flask and diluted to 100 ml with 1 (M) HCl. Then 2 ml of diluted solution was taken in another 100 ml volumetric flask and diluted to 100 ml with 1 (M) HCl.

Aliquot of 1 ml of the extract of each part was pipetted into different test tubes and 4 ml of anthrone reagent was added to the solution of each tube and mixed well. Glass marbles were placed on top of each tube to prevent loss of water by evaporation. The tubes were placed in a boiling water bath for 10 minutes, then removed and cooled. A reagent black was prepared by taking 1 ml of water 4 ml of anthrone reagent in test tube at 680 nm in a colorimeter. The amount of starch present in the sample was calculated by the following calculation.

Calculation

$$\text{The percentage of starch content (g per 100 g of samples)} = \frac{\text{Amount of starch}}{\text{Weight of sample}} \times 100$$

3.3.4: Statistical analysis

Data on nutrient contents (protein, lipid, carbohydrate) under different treatments were subjected to one way ANOVA (Analysis of Variance) using computer software SPSS (Statistical Package for Social Science, version-11). The mean values were also compared to see the significant difference from the DMRT (Duncan Multiple Range Test) after Gomez and Gomez (1984).

3.4: Results

Monthly variations

Monthly variations in the mean values of nutrient contents (protein, lipid and carbohydrate) under different treatments of feed items are presented in table 3.4 to 3.9.

Protein content significantly varied from 6.05±0.45% with T_6 (banana leaf) at 6th month (September, 2010) to 31.20±0.32% with treatment T_3 (mustard oilcake) at 2nd month (May, 2010). Lipid content significantly varied from 2.95±0.21% with treatment T_6 (banana leaf) at 5th month (August, 2010) to 13.72±0.36% with treatment T_3 (mustard oilcake) at 4th month (July, 2010). Carbohydrate significantly varied from 32.85±0.14% with treatment T_3 (mustard oilcake) at 4th month (July, 2010) to 66.35±0.32% with T_2 (wheat bran) at 3rd month (June, 2010). In the same feed item no significant difference in the nutrient content was found during the study period (Table 3.10 to 3.15).

Table-3.4: Variations in the mean values of nutrient (protein, lipid and carbohydrate) contents under different treatments at 1st month (April, 2010).

Nutrients	Treatments					
	T_1 (Rice, *Oryza sativa* bran)	T_2 (Wheat, *Trticum aestivum* bran)	T_3 (Mustard, *Brassica napus* Oilcake)	T_4 (*Azolla pinnata*)	T_5 (Grass, *Cynodon dactylon*)	T_6 (Leaf of banana, *Musa acuminata*)
Protein (%)	14.60±0.22^{d}	17.20±0.05^{c}	30.65±0.18^{a}	18.65±0.08^{b}	7.28±0.35^{e}	6.25±0.11^{f}
Lipid (%)	10.42±0.31^{b}	6.75±0.41^{c}	13.34±0.31^{a}	3.25±0.09^{d}	6.35±0.05^{c}	3.05±0.04^{d}
Carbohydrate (%)	44.25±0.41^{e}	66.20±0.36^{a}	32.86±0.18^{f}	50.36±0.75^{b}	46.58±0.12^{d}	48.85±0.36^{c}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-3.5: Variations in the mean values of nutrient (protein, lipid and carbohydrate) contents under different treatments at 2nd month (May, 2010).

Nutrients	Treatments					
	T_1 (Rice, *Oryza sativa* bran)	T_2 (Wheat, *Trticum aestivum* bran)	T_3 (Mustard, *Brassica napus* Oilcake)	T_4 (*Azolla pinnata*)	T_5 (Grass, *Cynodon dactylon*)	T_6 (Leaf of banana, *Musa acuminata*)
Protein (%)	13.92±0.19^{d}	17.05±0.12^{c}	31.20±0.32^{a}	18.45±0.41^{b}	7.32±0.25^{e}	6.20±0.21^{f}
Lipid (%)	10.50±0.25^{b}	6.66±0.69^{c}	13.24±0.47^{a}	3.15±0.12^{d}	6.28±0.06^{c}	3.12±0.11^{d}
Carbohydrate (%)	43.72±0.19^{e}	65.75±0.32^{a}	32.90±0.25^{f}	50.45±0.61^{b}	46.30±0.41^{d}	47.98±0.26^{c}

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

Table-3.6: Variations in the mean values of nutrient (protein, lipid and carbohydrate) contents under different treatments at 3rd month (June, 2010).

Nutrients	Treatments					
	T_1 (Rice, *Oryza sativa* bran)	T_2 (Wheat, *Trticum aestivum* bran)	T_3 (Mustard, *Brassica napus* Oilcake)	T_4 (*Azolla pinnata*)	T_5 (Grass, *Cynodon dactylon*)	T_6 (Leaf of banana, *Musa acuminata*)
Protein (%)	14.65±0.19^{d}	17.25±0.12^{c}	30.50±0.32^{a}	18.35±0.41^{b}	7.45±0.25^{e}	6.32±0.21^{f}
Lipid (%)	10.64±0.25^{b}	6.80±0.69^{c}	13.25±0.47^{a}	3.12±0.12^{d}	6.45±0.06^{c}	3.10±0.11^{d}
Carbohydrate (%)	43.85±0.19^{e}	66.35±0.32^{a}	33.10±0.25^{f}	50.20±0.61^{b}	45.95±0.41^{d}	48.10±0.26^{c}

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

Table-3.7: Variations in the mean values of nutrient (protein, lipid and carbohydrate) contents under different treatments at 4th month (July, 2010).

Nutrients	Treatments					
	T_1 (Rice, *Oryza sativa* bran)	T_2 (Wheat, *Trticum aestivum* bran)	T_3 (Mustard, *Brassica napus* Oilcake)	T_4 (*Azolla pinnata*)	T_5 (Grass, *Cynodon dactylon*)	T_6 (Leaf of banana, *Musa acuminata*)
Protein (%)	14.50±0.36[d]	16.95±0.24[c]	30.25±0.15[a]	18.45±0.32[b]	7.15±0.14[e]	6.12±0.31[f]
Lipid (%)	10.20±0.21[b]	7.12±0.46[c]	13.72±0.36[a]	3.35±0.18[d]	6.23±0.12[c]	3.20±0.17[d]
Carbohydrate (%)	44.20±0.24[e]	66.32±0.26[a]	32.85±0.14[f]	50.15±0.54[b]	46.85±0.38[d]	48.30±0.31[c]

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

Table-3.8: Variations in the mean values of nutrient (protein, lipid and carbohydrate) contents under different treatments at 5th month (August, 2010).

Nutrients	Treatments					
	T_1 (Rice, *Oryza sativa* bran)	T_2 (Wheat, *Trticum aestivum* bran)	T_3 (Mustard, *Brassica napus* Oilcake)	T_4 (*Azolla pinnata*)	T_5 (Grass, *Cynodon dactylon*)	T_6 (Leaf of banana, *Musa acuminata*)
Protein (%)	14.22±0.28[d]	17.10±0.34[c]	30.15±0.11[a]	18.75±0.24[b]	7.25±0.19[e]	6.14±0.36[f]
Lipid (%)	10.24±0.15[b]	6.47±0.32[c]	13.22±0.18[a]	3.14±0.34[d]	6.21±0.18[c]	2.95±0.21[d]
Carbohydrate (%)	44.32±0.20[e]	66.12±0.15[a]	32.98±0.31[f]	50.20±0.17[b]	46.70±0.19[d]	48.90±0.35[c]

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

Table-3.9: Variations in the mean values of nutrient (protein, lipid and carbohydrate) contents under different treatments at 6th month (September, 2010).

Nutrients	Treatments					
	T_1 (Rice, *Oryza sativa* bran)	T_2 (Wheat, *Trticum aestivum* bran)	T_3 (Mustard, *Brassica napus* Oilcake)	T_4 (*Azolla pinnata*)	T_5 (Grass, *Cynodon dactylon*)	T_6 (Leaf of banana, *Musa acuminata*)
Protein (%)	14.50 ± 0.24^{d}	17.22 ± 0.18^{c}	30.45 ± 0.17^{a}	18.80 ± 0.26^{b}	7.12 ± 0.23^{e}	6.05 ± 0.45^{f}
Lipid (%)	10.45 ± 0.26^{b}	6.32 ± 0.38^{c}	13.20 ± 0.19^{a}	3.10 ± 0.41^{d}	6.32 ± 0.28^{c}	2.96 ± 0.41^{d}
Carbohydrate (%)	44.20 ± 0.16^{e}	65.99 ± 0.23^{a}	33.02 ± 0.46^{f}	49.88 ± 0.27^{b}	45.76 ± 0.14^{d}	48.85 ± 0.24^{c}

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

Table-3.10: Monthly variations in nutrient (protein, lipid and carbohydrate) contents with treatment T_1 (Rice, *Oryza sativa* bran).

Nutrients	Months					
	April	May	June	July	August	September
Protein (%)	14.60 ± 0.22^{a}	13.92 ± 0.19^{a}	14.65 ± 0.19^{a}	14.50 ± 0.36^{a}	14.22 ± 0.28^{a}	14.50 ± 0.24^{a}
Lipid (%)	10.42 ± 0.31^{a}	10.50 ± 0.25^{a}	10.64 ± 0.25^{a}	10.20 ± 0.21^{a}	10.24 ± 0.15^{a}	10.45 ± 0.26^{a}
Carbohydrate (%)	44.25 ± 0.41^{a}	43.72 ± 0.19^{a}	43.85 ± 0.19^{a}	44.20 ± 0.24^{a}	44.32 ± 0.20^{a}	44.20 ± 0.16^{a}

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

Table-3.11: Monthly variations in nutrient (protein, lipid and carbohydrate) contents with treatment T_2 (Wheat, *Trticum aestivum* bran).

Nutrients	Months					
	April	May	June	July	August	September
Protein (%)	17.20±0.05[a]	17.05±0.12[a]	17.25±0.12[a]	16.95±0.24[a]	17.10±0.34[a]	17.22±0.18[a]
Lipid (%)	6.75±0.41[a]	6.66±0.69[a]	6.80±0.69[a]	7.12±0.46[a]	6.47±0.32[a]	6.32±0.38[a]
Carbohydrate (%)	66.20±0.36[a]	65.75±0.32[a]	66.35±0.32[a]	66.32±0.26[a]	66.12±0.15[a]	65.99±0.23[a]

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

Table-3.12: Monthly variations in nutrient (protein, lipid and carbohydrate) contents with treatment T_3 (Mustard, *Brassica napus* Oilcake).

Nutrients	Months					
	April	May	June	July	August	September
Protein (%)	30.65±0.18[a]	31.20±0.32[a]	30.50±0.32[a]	30.25±0.15[a]	30.15±0.11[a]	30.45±0.17[a]
Lipid (%)	13.34±0.31[a]	13.24±0.47[a]	13.25±0.47[a]	13.72±0.36[a]	13.22±0.18[a]	13.20±0.19[a]
Carbohydrate (%)	32.86±0.18[a]	32.90±0.25[a]	33.10±0.25[a]	32.85±0.14[a]	32.98±0.31[a]	33.02±0.46[a]

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

Table-3.13: Monthly variations in nutrient (protein, lipid and carbohydrate) contents with treatment T_4 (*Azolla pinnata*).

Nutrients	Months					
	April	May	June	July	August	September
Protein (%)	18.65±0.08[a]	18.45±0.41[a]	18.35±0.41[a]	18.45±0.32[a]	18.75±0.24[a]	18.80±0.26[a]
Lipid (%)	3.25±0.09[a]	3.15±0.12[a]	3.12±0.12[a]	3.35±0.18[a]	3.14±0.34[a]	3.10±0.41[a]
Carbohydrate (%)	50.36±0.75[a]	50.45±0.61[a]	50.20±0.61[a]	50.15±0.54[a]	50.20±0.17[a]	49.88±0.27[a]

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

Table-3.14: Monthly variations in nutrient (protein, lipid and carbohydrate) contents with treatment T_5 (Grass, *Cynodon dactylon*).

Nutrients	Months					
	April	May	June	July	August	September
Protein (%)	7.28±0.35[a]	7.32±0.25[a]	7.45±0.25[a]	7.15±0.14[a]	7.25±0.19[a]	7.12±0.23[a]
Lipid (%)	6.35±0.05[a]	6.28±0.06[a]	6.45±0.06[a]	6.23±0.12[a]	6.21±0.18[a]	6.32±0.28[a]
Carbohydrate (%)	46.58±0.12[a]	46.30±0.41[a]	45.95±0.41[a]	46.85±0.38[a]	46.70±0.19[a]	45.76±0.14[a]

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

Table-3.15: Monthly variations in nutrient (protein, lipid and carbohydrate) contents with treatment T_6 (Leaf of banana, *Musa acuminata*).

Nutrients	Months					
	April	May	June	July	August	September
Protein (%)	6.25±0.11[a]	6.20±0.21[a]	6.32±0.21[a]	6.12±0.31[a]	6.14±0.36[a]	6.05±0.45[a]
Lipid (%)	3.05±0.04[a]	3.12±0.11[a]	3.10±0.11[a]	3.20±0.17[a]	2.95±0.21[a]	2.96±0.41[a]
Carbohydrate (%)	48.85±0.36[a]	47.98±0.26[a]	48.10±0.26[a]	48.30±0.31[a]	48.90±0.35[a]	48.85±0.24[a]

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

Mean variations

The variations in the mean values of nutrient contents (protein, lipid and carbohydrate) with different treatments of feed items are presented in table 3.16 and fig. 3.1.

Protein content significantly varied from 6.18±0.13% with treatment T_6 (banana leaf) to 30.53±0.40% with treatment T_3 (mustard oilcake). Lipid content significantly varied from 3.06±0.09% with treatment T_6 (banana leaf) to 13.33±0.10% with treatment T_3 (mustard oilcake). Carbohydrate significantly varied from 32.95±0.29% with treatment T_3 (mustard oilcake) to 66.12±0.47% with treatment T_2 (wheat bran).

Table-3.16: Variations in the mean values of nutrient (protein, lipid and carbohydrate) contents under different treatments during study period.

Nutrients	Treatments					
	T_1 (Rice, *Oryza sativa* bran)	T_2 (Wheat, *Trticum aestivum* bran)	T_3 (Mustard, *Brassica napus* Oilcake)	T_4 (*Azolla pinnata*)	T_5 (Grass, *Cynodon dactylon*)	T_6 (Leaf of banana, *Musa acuminata*)
Protein (%)	$14.40±0.32^{d}$	$17.13±0.07^{c}$	$30.53±0.40^{a}$	$18.58±0.09^{b}$	$7.26±0.18^{e}$	$6.18±0.13^{f}$
Lipid (%)	$10.41±0.31^{b}$	$6.69±0.30^{c}$	$13.33±0.10^{a}$	$3.19±0.10^{d}$	$6.31±0.13^{c}$	$3.06±0.09^{d}$
Carbohydrate (%)	$44.09±0.67^{e}$	$66.12±0.47^{a}$	$32.95±0.29^{f}$	$50.21±0.54^{b}$	$46.36±0.16^{d}$	$48.50±0.51^{c}$

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

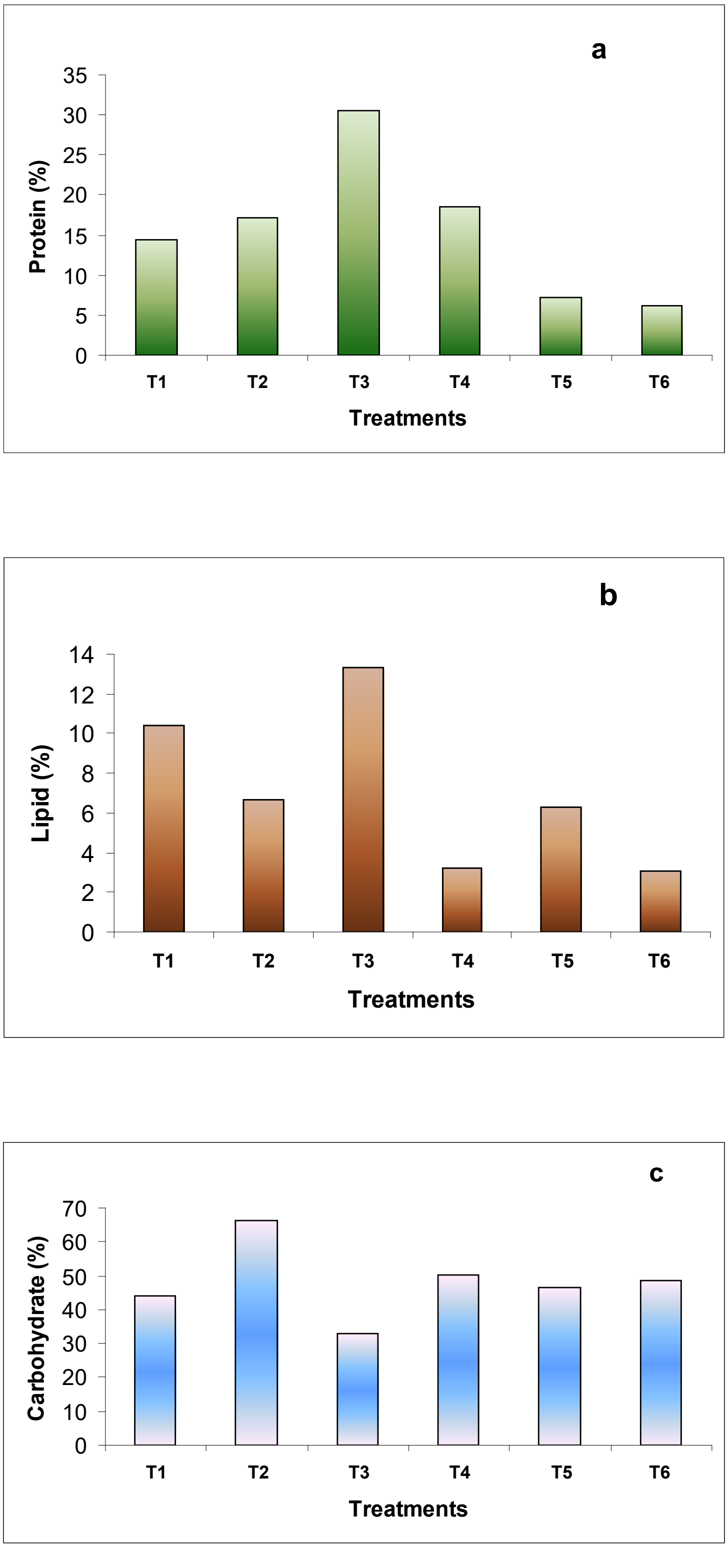


Fig. 3.1. Variations in the mean values of nutrient contents under different fish feed items (a. Protein; b. Lipid; c. carbohydrate).

3.5: Discussion

Monthly variations of the nutrient contents

Protein content varied from 6.05±0.45% with (T_6 at 6th month) to 31.20±0.32% (T_3 at 2nd month). Lipid content ranged from 2.95±0.21% (T_6 at 5th month) to 13.72±0.36% (T_3 at 4th month). Carbohydrate content ranged from 32.85±0.14% (T_3 at 4th month) to 66.35±0.32% (T_2 at 3rd month). Suresh and Mandal (2000) worked on the determination of nutritive value of rice bran, mustard oil cake and Azolla for a period of 4 months from July to October. In rice bran they found crude protein and crude fibre as 12.6% and 21.9%, respectively. In mustard oilcake, crude protein and crude fibre was 38.6% and 6.8%, respectively and in Azolla, crude protein and crude fibred was 26.5% and 20.4%, respectively. Sithara and Kamalaveni (2008) worked on the formulation of low cost fish feed using Azolla as a protein supplement during September to March and reported 20-25.5% protein in Azolla. Ebrahim *et al*. (2007) used Azolla as tilapia diet for a period of 90 days in summer season and reported 20% protein in Azolla. Fasakin and Balogan (2001) worked on the nutritional aspects of Azolla in August, 1997 and reported 20.9% protein in Azolla.

Present findings also indicated that in case of same feed item, no significant difference was found in the nutrient content at different months (Table 3.10 to 3.15). This might be due to no major change in the temperature was found to affect the growth and composition of Azolla during the study period (Appendix-1). This statement was almost agreed with Lumpkin and Plucknett (1982) who reported that change in Azolla composition was subjected to change in environment. Statement also agreed with Van-Hove *et al*. (1987) and Ebrahim *et al*. (2007) who reported that change in Azolla composition was subjected to change in species.

Mean variation of the nutrient contents

In the present study the protein content varied from 6.18±0.13% (T_6, banana leaf) to 30.53±0.40% (T_3, mustard oilcake), lipid content varied from 3.06±0.09% (T_6, banana leaf) to 13.33±0.10% (T_3, mustard oilcake) and carbohydrate content varied from 32.95±0.29% (T_3, mustard oilcake) to 66.12±0.47% (T_2, wheat bran). The highest protein and lipid content was found in treatment T_3 (mustard oilcake) whereas the highest carbohydrate content was found in treatment T_2, wheat bran (66.12±0.47%) followed by T_4, Azolla

(50.21±0.54%), T_6, banana leaf (48.50±0.51%), T_5, grass (46.36±0.16%), T_1, rice bran (44.09±0.67%), T_3, mustard oilcake (32.95±0.29%). Hepher (1988) reported the protein content of ricebran, wheat bran, oil cake and Azolla as 11.88%, 14.57%, 30-33% and 19.27%, respectively. Banerjee and Matai (1990) determined the nutritive status of *Azolla pinnata* and reported protein as 21.9% and Lipid as 3.8%. Gavina (1994) reported crude protein of 20.98%, crude fat of 5.17% and crude fiber of 19.30% in Azolla. Tavares *et al.* (2008) observed 38.8% crude protein, 3.8% crude fat and 13.2% crude fiber in dried duck weed. They also reported that the protein content of duckweeds growing on nutrient poor and nutrient rich water varied between 15-25% and 35-45% (Dry matter basis), respectively.

In case of conventional feed items the major nutrient like protein varied from 14.40±0.32% (rice bran) to 30.53±0.40% (mustard oilcake). Whereas in case of non-conventional feed items the protein varied from 6.18±0.13% (banana leaf) to 18.58±0.09% (Azolla). Being an omnivore, the fish can also feed on vegetation (Santhanam *et al*., 1990) and may be able to assimilate Azolla in the diets.

The chemical composition of Azolla species varies with ecotypes and with the ecological conditions and the phase of growth. The crude protein content is about 19-30 percent dry matter basis during the optimum conditions for growth (Peters *et al*., 1979; Becking, 1979). The protein contents of Azolla species are comparable to or higher than that of most other aquatic macrophytes. Aquatic weeds' are highly nutritious with protein content of 20-30%, when cultivated in nutrient rich waters (Culley *et al*., 1981). Importantly, they are preferred food of a wide range of herbivorous fish such as grass carp (*Ctenopharyngodon idella*), silver barb (*Barbonymus gonionotus*, *Puntius jerdoni*), tilapias (*Oreochromis niloticus*, *Tilapia rendalli*, *Tilapia zillii*) and rohu (*Labeo rohita*) (Singh *et al*., 1967; Gaiger *et al*., 1984).

Overall findings indicated that inspite of having variations in nutrient contents, monthly supply of nutrients was almost same respective feed item under non-conventional feeds as with conventional feeds. Mean values of the nutrient contents under non-conventional feed items are found potentials for the development of low cost aquaculture.

Fish feed generally constitutes 60–70% of the operational cost in intensive and semi- intensive aquaculture system (Singh *et al*., 2006). The fish feed used in aquaculture is quite expensive, irregular and short in supply in many third world countries. These feeds are sometimes adulterated, contaminated with pathogen as well as containing harmful chemicals for human health. Naturally there is a need for the development of healthy, hygienic fish feed which influences the production as well as determines the quality of cultured fish. Considering the importance of nutritionally balanced and cost-effective alternative diets for fish, almost similar expression to evaluate the nutritive value of different non-conventional feed resources, including terrestrial and aquatic macrophytes was found with Wee and Wang (1987) and Mondal and Ray (1999). However potentials roles of aquatic and terrestrial macrophytes as supplementary feeds in fish farming were also found to be expressed with Bardach *et al*. (1972) and Edwards (1990).

3.6: Conclusion

In case of conventional feed items, protein, lipid and carbohydrate varied from 14.40±0.32% to 30.53±0.40%, 6.69±0.30% to 13.33±0.10% and 32.95±0.29% to 66.12±0.47%. In case of non-conventional feed items, protein, lipid and carbohydrate varied from 6.18±0.13% to 18.58±0.09%, 3.06±0.09% to 6.31±0.13% and 46.36±0.16% to 50.21±0.54%. Inspite of variations weeds are moderately nutritive and low cost effective diets for fish. However, the present study did not evaluate the fish production and economics of feed and weed based systems.

3.7: Recommendation

Present findings explored the nutritive aspects of both conventional and non-conventional feed items and question raised about the response of utilizing the feed specially of aquatic weeds to fish growth and economics. Therefore, it is recommended to conduct further study on the evaluation of fish production and economics under different feed and weed based systems in polyculture ponds.

CHAPTER FOUR

Evaluation of fish production and economics under conventional feed and weed based systems in polyculture ponds

4.1: Introduction

Supplementary feeds are the major expenditure in any fish culture operation (Mukhopadhyay and Jena, 1999; Fasakin, 1999) which contributes to cost increase per unit production (New and Csavas, 1993). To avoid increasing feed cost with conventional feed items, efforts are being made towards the use of various non-conventional feed sources as ingredients in fish feed (Ali *et al*., 2006). The weed based system refers to the use of some inputs from plant sources, eg. weeds or grasses or leaves or macrophytes like duckweeds, Azolla etc. as supplemental feed in fish production. These inputs are consumed first as feed by herbivorous fish and subsequently a part of the semi digested faecal matter of the macrophytes feeding fishes are consumed by the other fishes and the remaining part will be recycled in food chain as nutrients for primary production, thus they have potentiality to increase the total fish production of aquaculture system (Grover *et al*., 2000).

Aquatic weeds have been utilized as food components and thus have played an important role in culture of herbivorous fish since 4000 years ago in Egypt and 2500 years ago in the Orient, including Indian subcontinent (Bardach *et al*., 1972). Okeyo (1989) listed a number of aquatic macrophytes (*Azolla pinnata*, *Chara* sp., *Eichhornia crassipes*, *Ipomoea aquatica*, *Lemna minor*, *Nymphae* sp., *Trapa natans*, *Wolffia arrhiza*, *Lactuca sativa*, *Typha latifolia*) as potential source of nutrients which are directly used as food components by a number of herbivorous fish. *Azolla pinnata* enhances nitrogen in semi-intensive pisciculture systems (Ayyappan *et al*., 1993) and acts direct food by some macrophytophagous fish (Cassani, 1981; Antonie *et al*., 1987). Duckweeds might be having as much potential as fish foods that could be utilized in preparation of suitable fish feed essential in expansion of low-cost aquaculture system in the tropics (Hassan and Edwards, 1992). Fresh duckweed (and also the dried meal) is suited to intensive production of herbivorous fish (Gaiger *et* *al.,* 1984) and duckweed is converted efficiently to live weight gain by carp and tilapia (Van-Dyke and Sutton, 1977; Hepher and Pruginin, 1979; Robinette *et al.,* 1980; Hassan and Edwards, 1992; Skillicorn *et al.*, 1993).

Most of the fish farmers of Bangladesh are resource poor. These resource poor farmers need suitable low cost aquaculture technology to constituting fish farming. Carp polyculture contributes 34.61% of total fish production (DoF, 2012). Weed can be grown abundantly with minimum cost and can be made available for carp polyculture with much cheaper price than other alternative protein sources in Bangladesh (Grover *et al.*, 2000). Researches carried out on the application of weed have so far been centered on the wastewater treatment (Oron, 1994; Alaerts *et al.*, 1996; Vander Steen *et al.*, 1998). However, these research efforts also indicate that comprehensive studies are required to explore the nutrients, production and economics of fish farming based on both conventional and non-conventional feed items specially for the promotion of weed based aquaculture in Bangladesh. Already popularities of locally available weeds to have the major nutrients throughout the major carp polyculture systems are explored well (experiment-1). Unfortunately no effort is found to explore the growth and economics of fish farming of weed based system with conventional feed system. Therefore, the present study aimed at evaluating the fish production and economics under different treatments of weed and feed based systems in polyculture ponds.

4.2 Specific objectives

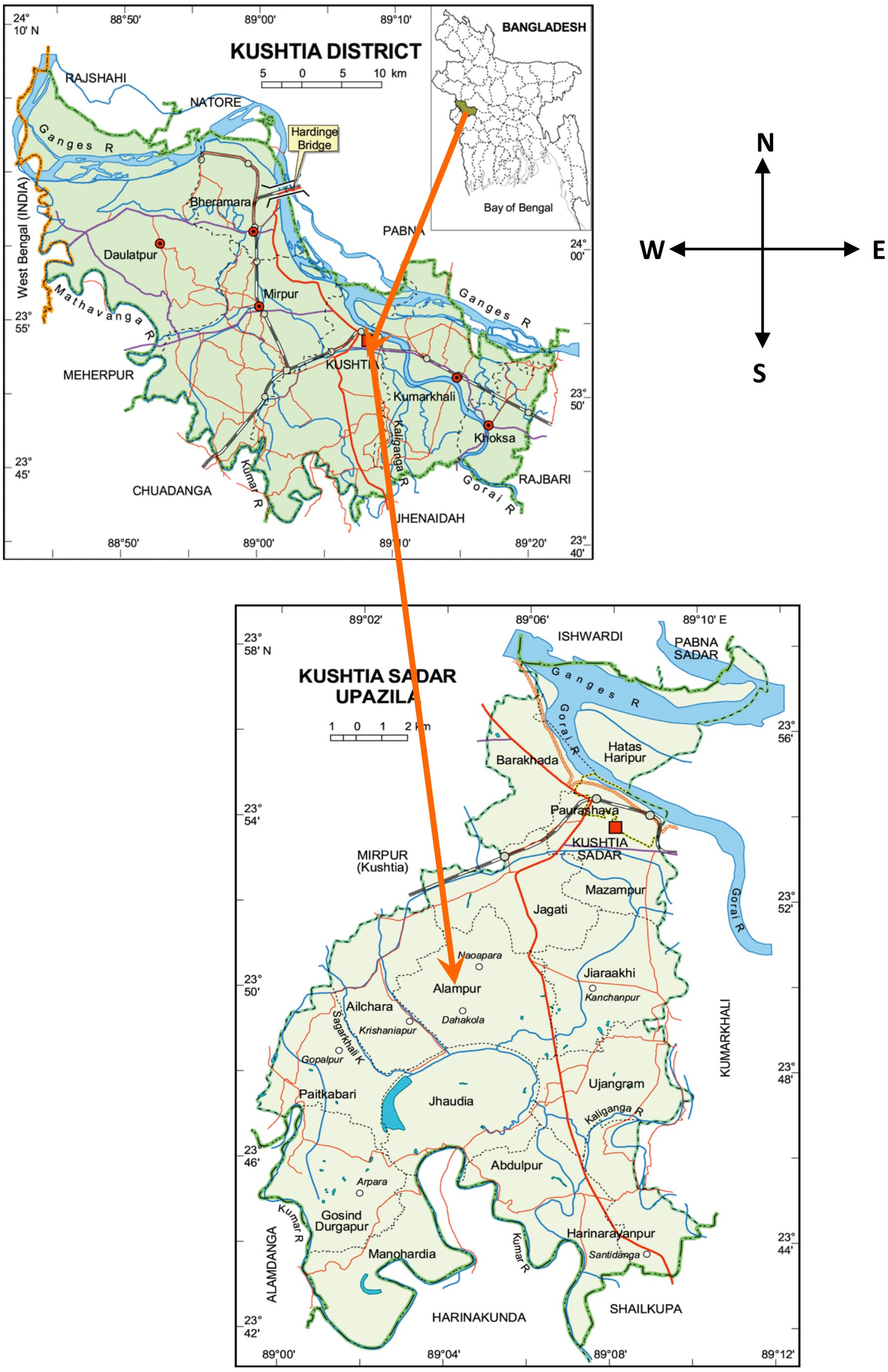
The specific objectives of this study were as follows-

- to monitor the water quality parameters (in terms of temperature, transparency, dissolved oxygen, pH, alkalinity and CO_2) in ponds under different treatments of weed and feed based systems;
- to evaluate fish production under different treatments of weed and feed based systems;
- to evaluate the economics of fish farming under different treatments of weed and feed based systems; and
- to recommend suitable weed as feed for the application in the carp polyculture ponds.

4.3: Materials and methods

4.3.1: Duration and location of the study

The study was conducted for a period of six months (April 2011 to September 2011) at Alampur village of Sadar Upazila under Kushtia district, Bangladesh (Map 4.1).



Map 4.1 : Shows the study area.

4.3.2: Description of the study ponds

A total of 12 ponds (average water area of 0.18ha and depth of 1.9 m) were selected for the present study. All the ponds were rain-fed and well exposed to sunlight (Plate 4.1).

4.3.3: Experimental design

The experiment was designed under Randomized Completely Block Design (RCBD) with four treatments (T_0, T_1, T_2 and T_3) of fish feeds, each with three replications. The treatment assignment was as follows-

T_0 : Ponds fed with conventional feed like rice bran, wheat bran and mustard oilcake (no weed was used as fish feed).

T_1 : Azolla (*Azolla pinnata*) fed ponds.

T_2 : Grass (*Cynodon dactylon*) fed ponds.

T_3 : Banana (*Musa acuminata*) leaf fed ponds.

Stocking density and stocking ratio/combination of fish species (Table 4.1) were same for all the treatments.

4.3.4: Pond management

Aquatic weeds were removed from all the ponds manually. Predatory fish and other unwanted species were removed through repeated netting.

Liming was done at a rate of 250 kg/ha before 7 days of fertilization. All the ponds were fertilized with cowdung (1500 kg/ha), urea (60 kg/ha) and Triple Super Phosphate (TSP) (60 kg/ha) as basal dose.

For Azolla fed ponds, one tenth area of the research ponds were used as Azolla bank according to Grover *et al*. (2000). Azolla bank was prepared by bamboo fencing (locally called 'Bana'). In Azolla bank, compost manure was deposited (2470 kg/ha). Azolla seeds were introduced in Azolla bank at the rate of 1000 kg/ha for available supply of Azolla during culture period.

Fishes were stocked (11115 fish/ha) in all ponds after five days of basal fertilization. All the ponds were stocked with seven species of fishes (Table 4.1). Mean initial weight of *Hypophthalmichthyes molitrix*, *Catla catla*, *Labeo rohita*, *Cirrhinus cirrhosus*, *Cyprinus carpio*, *Ctenopharyngodon idella* and *Barbonymus gonionotus* were 62, 64, 57, 54, 63, 65 and 25 g, respectively.

Fish seeds were collected from local government fish farm. Stocking of fish seeds were done at early morning.

Table 4.1: Stocking density and stocking ratio/combination of the stocked fish species.

Pond layer	Fish species	No. of fish/decimal	No. of fish/ha
Surface layer	1. *Hypophthalmichthyes molitrix* 2. *Catla catla*	9 3	2223 741
Middle layer	3. *Labeo rohita*	10	2470
Bottom layer	4. *Cirrhinus cirrhosus* 5. *Cyprinus carpio*	5 3	1235 741
All layer	6. *Ctenopharyngodon idella* 7. *Barbonymus gonionotus*	5 10	1235 2470
	Total	45	11115

After stocking urea was applied (2.5 kg/ha/day) for ponds under all the treatments except the treatment T_1 (Azolla fed ponds). However, TSP was applied (2.5 kg/ha/day) for ponds under all treatments as periodic fertilization.

In ponds under treatment T_0 commonly available conventional feed ingredients such as rice bran (30%), wheat bran (30%) and oilcake (40%) were used as supplementary feed daily at the rate of 4% of body weight of total fish for the first 2 months (April and May), 3% for the next 2 months (June and July) and finally 2% for the last 2 months (August and September) of culture period. Fish were fed twice a day at 09:00-10:00 hours and at 03:00-04:00 hours with 50% of the ration allocated at each time.

In ponds under treatments T_1, T_2 and T_3, Azolla (100%), grass (100%) and banana leaf (100%) were supplied as supplementary feed daily at the rate of 100% of the body weight of herbivorous fishes (*C. idella* and *B. gonionotus*).

Azolla was supplied from Azolla bank, whereas grass and banana leaves were collected locally and chopped into very small pieces during application.

4.3.6: Water quality monitoring

Some important physico-chemical parameters of water such as water temperature, transparency, dissolved oxygen (DO), pH, alkalinity and carbon-dioxide (CO_2) were monitored fortnightly between 10:00 AM to 11:00 AM for the present study (Plate 4.2).

4.3.6.1: Water temperature

During the study period, water temperature was recorded with the help of a celsius thermometer at 20-30 cm depth of water. The data were expressed as °C.

4.3.6.2: Water transparency

Measurement of limit of visibility i.e. penetration of light in water was done by a Secchi disc. The data thus obtained, were expressed as secchi disc depth in centimeter.

4.3.6.3: Dissolved oxygen (DO)

The dissolved oxygen concentration of water was determined by the aid of a water quality test kit (HACH kit FF-2, USA). Alkaline iodide-azide powder pillows, manganese sulfate powder pillows, sodium thiosulfate titration cartridge (0.2000 N), starch indicator solution and sulfamic acid powder pillows were used for determination of dissolved oxygen. The concentration of dissolved oxygen thus estimated was expressed in milligram per litter (mg/l) of water.

4.3.6.4: Hydrogen ion concentration (pH)

pH was measured by using HACH kit (FF-2, USA). Wide range pH 4 pH indicator solution (1919-00) were used for determination of water pH. A colour comparator disc ranging from 1-14 was also used for this purpose.

4.3.6.5: Alkalinity

Alkalinity was determined through digital titration by the help of a HACH kit (FF-2, USA). Bromcresol green-methyl red powder pillows, phenolphthalein powder pillows and sulfuric acid titration cartridge (0.1600 N) were used for total alkalinity determination. It was also expressed as mg/l of water.

4.3.6.6: Free carbon dioxide (CO_2)

Free carbon dioxide was determined through digital titration by the help of a HACH kit (FF-2, USA). Phenolphthalein powder pillows and sodium hydroxide titration cartridge (0.3636 N) were used for determination of carbon dioxide. It was also expressed as mg/l of water.

4.3.7: Growth monitoring of fishes

At least 10% (by number) of the fish in each pond were randomly sampled on a monthly basis with a cast net. On each sampling day, individual fish from each pond were weighed and measured (Plate 4.3). The purpose was to determine fish growth in weight and to adjust the ration. Following growth parameters were used for the present study.

Weight gain (g) = Mean final weight (g) - Mean initial weight (g)

Final weight (g) = Weight of fish at harvest (g)

Specific Growth Rate, SGR (% bwd^{-1}) = [L_n (final weight) – L_n (initial weight)] / culture period (days) $\times$ 100

(Brown, 1957)

$$\text{Survival rate (\%)} = \frac{\text{Number of fish harvested}}{\text{Number of fish stocked}} \times 100$$

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

4.3.8: Economics

Simple economical analysis of the different treatments was performed during the study period. On the basis of the fixed and variable expenditure, the total cost (BDT/ha) was estimated. At the end of the experiment, fishes were sold locally and the gross benefit (BDT/ha) was estimated. Net benefit (BDT/ha) was estimated by deducting the total cost from gross benefit. The following parameters were used to explore the economics of different treatments:

$$\text{Net profit margin (\%)} = \frac{\text{Net benefit}}{\text{Total investment}} \times 100$$

$$\text{CBR (Cost-Benefit Ratio)} = \frac{\text{Net benefit}}{\text{Total investment}}$$

4.3.9: Statistical analysis

Data on water quality parameters, fish production and economics under different treatments were subjected to one way ANOVA (Analysis of Variance) using computer software SPSS (Statistical Package for Social Science, version-11). The mean values were also compared to see the significant difference from the DMRT (Duncan Multiple Range Test) after Gomez and Gomez (1984).

Plate 4.1: Experimental ponds.

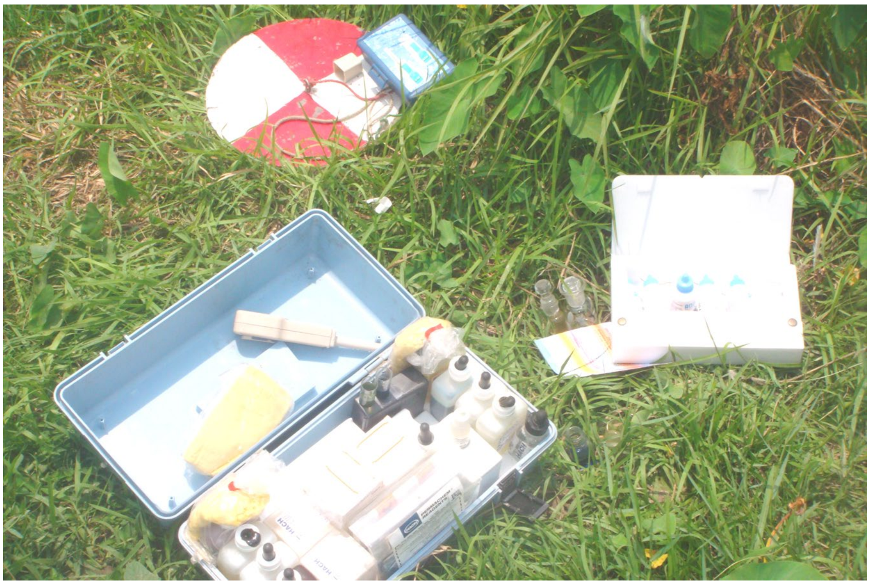


Plate 4.2 Monitoring water quality parameters.

Plate 4.3 Measurement of growth of fishes.

4.4: Results

4.4.1: Water quality

4.4.1.1: Fortnightly variations

The variations in the mean values of water quality parameters in different treatments at different fortnights are presented in table 4.2 to table 4.13.

Water temperature

During the study period, water temperature varied from 29.58±0.03 to 32.23±0.08°C. The minimum value was recorded in treatment T_0 at 1st fortnight whereas the maximum value was recorded in treatment T_0 at 6th fortnight.

Water transparency

Water transparency value was found to range from 30.00±0.58 to 35.00±0.00 cm. The minimum value was recorded in treatment T_2 at 7th fortnight whereas the maximum value was recorded in treatment T_1 at 1st fortnight.

Dissolved Oxygen (DO)

Dissolved oxygen of water varied from 4.90±0.06 to 6.17±0.12 mg/l. The minimum value was recorded in treatment T_2 at 6th fortnight whereas the maximum value was recorded in treatment T_1 at 10th fortnight.

Hydrogen ion concentration (pH)

pH value of water varied from 7.03±0.03 to 7.87±0.09. The minimum value was recorded in treatment T_3 at 6th fortnight whereas the maximum value was recorded in treatment T_0 at 12th fortnight.

Alkalinity

Alkalinity of water was found to range from 109.22±1.33 to 120.00±1.15 mg/l. The minimum value was recorded in treatment T_3 at 1st fortnight whereas the maximum value was recorded in treatment T_0 at 9th fortnight.

Free carbon dioxide (CO_2)

Free CO_2 value was found to range from 2.49±0.07 to 3.46±0.03 mg/l. The minimum value was recorded in treatment T_1 at 4th fortnight whereas the maximum value was recorded in treatment T_3 at 12th fortnight.

Among the water quality parameters the values of transparency at 1st, 10th and 12th fortnights, DO at 6th, 9th, 11th and 12th fortnights, pH at 12th fortnight, alkalinity at 8th and 9th fortnights and CO_2 at 10th fortnight differed significantly with the treatments.

Table-4.2: Variations in the mean values of water quality parameters under different treatments at 1st fortnight

Parameters \ Treatments	T_0	T_1	T_2	T_3
Water temperature (°C)	29.58 ± 0.03^{a}	30.12 ± 0.21^{a}	30.23 ± 0.14^{a}	30.05 ± 0.09^{a}
Transparency (cm)	$32.67 \pm 0.88a^{b}$	35.00 ± 0.00^{a}	32.00 ± 1.15^{b}	32.33 ± 0.67^{ab}
DO (mg/l)	5.18 ± 0.12^{a}	5.32 ± 0.06^{a}	5.13 ± 0.09^{a}	5.17 ± 0.09^{a}
pH	7.20 ± 0.06^{a}	7.40 ± 0.06^{a}	7.10 ± 0.06^{a}	7.20 ± 0.10^{a}
Alkalinity (mg/l)	116.00 ± 1.15^{a}	118.23 ± 0.45^{a}	114.33 ± 4.18^{a}	109.22 ± 1.33^{a}
Free CO_2 (mg/l)	3.23 ± 0.02^{a}	2.52 ± 0.07^{a}	3.12 ± 0.03^{a}	3.02 ± 0.06^{a}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.3: Variations in the mean values of water quality parameters under different treatments at 2nd fortnight

Parameters \ Treatments	T_0	T_1	T_2	T_3
Water temperature (°C)	30.46 ± 0.14^{a}	30.69 ± 0.23^{a}	30.85 ± 0.06^{a}	30.58 ± 0.06^{a}
Transparency (cm)	31.67 ± 0.67^{a}	31.00 ± 0.00^{a}	31.33 ± 0.33^{a}	31.67 ± 1.67^{a}
DO (mg/l)	5.27 ± 0.09^{a}	5.35 ± 0.15^{a}	5.00 ± 0.12^{a}	5.27 ± 0.03^{a}
pH	7.13 ± 0.09^{a}	7.30 ± 0.09^{a}	7.13 ± 0.09^{a}	7.17 ± 0.09^{a}
Alkalinity (mg/l)	113.33 ± 1.45^{a}	112.00 ± 1.73^{a}	118.00 ± 3.51^{a}	111.33 ± 3.28^{a}
Free CO_2 (mg/l)	3.31 ± 0.11^{a}	2.85 ± 0.06^{a}	3.37 ± 0.02^{a}	3.33 ± 0.12^{a}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.4: Variations in the mean values of water quality parameters under different treatments at 3rd fortnight

Treatments / Parameters	T_0	T_1	T_2	T_3
Water temperature (°C)	31.61±0.09^a	30.98±0.05^a	31.25±0.11^a	31.54±0.09^a
Transparency (cm)	34.00±0.58^a	32.00±1.00^a	32.33±1.45^a	31.33±0.33^a
DO (mg/l)	5.12±0.17^a	5.36±0.15^a	5.13±0.03^a	5.17±0.09^a
pH	7.20±0.12^a	7.32±0.15^a	7.21±0.06^a	7.17±0.09^a
Alkalinity (mg/l)	110.00±1.73^a	111.00±2.08^a	113.33±0.33^a	112.33±2.03^a
Free CO_2 (mg/l)	3.12±0.03^a	2.95±0.01^a	3.02±0.23^a	3.09±0.11^a

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P <0.05$)

Table-4.5: Variations in the mean values of water quality parameters under different treatments at 4th fortnight

Treatments / Parameters	T_0	T_1	T_2	T_3
Water temperature (°C)	31.98±0.09^a	31.74±0.09^a	31.67±0.02^a	31.59±0.06^a
Transparency (cm)	33.33±0.67^a	33.00±0.58^a	33.67±0.88^a	33.00±1.53^a
DO (mg/l)	5.03±0.09^a	5.20±0.06^a	4.97±0.12^a	5.07±0.12^a
pH	7.17±0.07^a	7.27±0.07^a	7.20±0.12^a	7.10±0.15^a
Alkalinity (mg/l)	112.67±1.45^a	109.67±0.88^a	113.00±3.61^a	117.00±2.52^a
Free CO_2 (mg/l)	2.61±0.03^a	2.49±0.07^a	2.58±0.03^a	2.85±0.07^a

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P <0.05$)

Table-4.6: Variations in the mean values of water quality parameters under different treatments at 5th fortnight

Parameters \ Treatments	T_0	T_1	T_2	T_3
Water temperature (°C)	32.15±0.11[a]	31.92±0.06[a]	32.08±0.14[a]	31.96±0.02[a]
Transparency (cm)	32.67±0.88[a]	33.00±1.53[a]	33.00±1.53[a]	33.00±1.15[a]
DO (mg/l)	5.10±0.10[a]	5.23±0.03[a]	5.17±0.07[a]	4.93±0.13[a]
pH	7.30±0.06[a]	7.40±0.06[a]	7.27±0.09[a]	7.33±0.09[a]
Alkalinity (mg/l)	114.00±2.31[a]	113.33±4.26[a]	110.33±0.88[a]	117.00±2.08[a]
Free CO_2 (mg/l)	2.72±0.05[a]	2.55±0.06[a]	2.74±0.08[a]	2.77±0.05[a]

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.7: Variations in the mean values of water quality parameters under different treatments at 6th fortnight

Parameters \ Treatments	T_0	T_1	T_2	T_3
Water temperature (°C)	32.23±0.08[a]	32.04±0.24[a]	32.16±0.08[a]	31.98±0.02[a]
Transparency (cm)	31.67±0.33[a]	32.33±0.88[a]	31.33±0.88[a]	32.33±1.45[a]
DO (mg/l)	5.23±0.09[a]	5.30±0.06[a]	4.90±0.06[b]	5.10±0.00[a]
pH	7.13±0.09[a]	7.15±0.03[a]	7.13±0.15[a]	7.03±0.03[a]
Alkalinity (mg/l)	115.00±1.53[a]	113.67±3.84[a]	109.33±0.88[a]	112.67±0.88[a]
Free CO_2 (mg/l)	2.84±0.04[a]	2.72±0.11[a]	2.80±0.12[a]	2.84±0.05[a]

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.8: Variations in the mean values of water quality parameters under different treatments at 7th fortnight

Parameters \ Treatments	T_0	T_1	T_2	T_3
Water temperature (°C)	$31.85±0.14^a$	$31.92±0.11^a$	$32.05±0.15^a$	$31.98±0.06^a$
Transparency (cm)	$31.00±0.58^a$	$30.67±0.67^a$	$30.00±0.58^a$	$31.33±0.33^a$
DO (mg/l)	$5.03±0.09^a$	$5.23±0.03^a$	$5.16±0.14^a$	$5.07±0.09^a$
pH	$7.13±0.09^a$	$7.20±0.12^a$	$7.07±0.12^a$	$7.10±0.06^a$
Alkalinity (mg/l)	$114.33±1.67^a$	$116.00±2.52^a$	$114.67±1.33^a$	$114.67±2.03^a$
Free CO_2 (mg/l)	$2.87±0.09^a$	$2.79±0.06^a$	$2.89±0.03^a$	$2.86±0.06^a$

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.9: Variations in the mean values of water quality parameters under different treatments at 8th fortnight

Parameters \ Treatments	T_0	T_1	T_2	T_3
Water temperature (°C)	$31.71±0.08^a$	$31.62±0.02^a$	$31.55±0.12^a$	$31.39±0.05^a$
Transparency (cm)	$33.00±0.58^a$	$31.67±0.33^a$	$33.00±1.15^a$	$32.67±1.33^a$
DO (mg/l)	$5.07±0.07^a$	$5.20±0.10^a$	$5.13±0.07^a$	$5.13±0.03^a$
pH	$7.22±0.09^a$	$7.33±0.03^a$	$7.17±0.03^a$	$7.20±0.06^a$
Alkalinity (mg/l)	$115.33±1.45^{ab}$	$117.67±1.33^a$	$110.33±2.73^b$	$110.33±2.03^b$
Free CO_2 (mg/l)	$2.91±0.12^a$	$2.85±0.06^a$	$2.92±0.09^a$	$2.90±0.06^a$

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.10: Variations in the mean values of water quality parameters under different treatments at 9th fortnight

Parameters \ Treatments	T_0	T_1	T_2	T_3
Water temperature (°C)	31.37±0.09^a	31.36±0.18^a	31.26±0.12^a	31.24±0.10^a
Transparency (cm)	32.67±0.88^a	33.33±0.33^a	32.33±0.88^a	33.00±0.58^a
DO (mg/l)	5.73±0.07^{ab}	5.90±0.06^a	5.87±0.03^a	5.67±0.03^b
pH	7.20±0.12^a	7.31±0.12^a	7.24±0.07^a	7.17±0.07^a
Alkalinity (mg/l)	120.00±1.15^a	116.33±0.88^b	118.67±0.88^{ab}	118.00±1.15^{ab}
Free CO_2 (mg/l)	2.98±0.03^a	2.88±0.06^a	2.96±0.03^a	2.95±0.00^a

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

Table-4.11: Variations in the mean values of water quality parameters under different treatments at 10th fortnight

Parameters \ Treatments	T_0	T_1	T_2	T_3
Water temperature (°C)	31.44±0.09^a	31.23±0.03^a	31.31±0.17^a	31.21±0.05^a
Transparency (cm)	32.00±0.58^b	34.67±0.33^a	34.00±0.58^a	34.00±0.58^a
DO (mg/l)	6.13±0.09^a	6.17±0.12^a	6.13±0.09^a	6.13±0.03^a
pH	7.40±0.03^a	7.45±0.09^a	7.20±0.06^a	7.33±0.09^a
Alkalinity (mg/l)	115.67±1.20^a	115.00±1.00^a	117.00±1.15^a	114.33±0.88^a
Free CO_2 (mg/l)	3.14±0.02^a	2.88±0.03^b	3.10±0.03^b	2.95±0.03^b

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

Table-4.12: Variations in the mean values of water quality parameters under different treatments at 11th fortnight

Parameters \ Treatments	T_0	T_1	T_2	T_3
Water temperature (°C)	30.48±0.06^{a}	30.27±0.02^{a}	30.26±0.06^{a}	30.29±0.12^{a}
Transparency (cm)	31.67±0.88^{a}	33.00±0.58^{a}	32.00±1.00^{a}	31.67±0.88^{a}
DO (mg/l)	6.00±0.06^{ab}	6.05±0.03^{a}	5.87±0.03^{bc}	5.80±0.06^{c}
pH	7.27±0.13^{a}	7.56±0.09^{a}	7.50±0.12^{a}	7.33±0.03^{a}
Alkalinity (mg/l)	114.33±2.33^{a}	115.67±0.67^{a}	114.75±0.67^{a}	114.38±0.88^{a}
Free CO_2 (mg/l)	3.22±0.03^{a}	3.05±0.03^{a}	3.10±0.03^{a}	3.20±0.06^{a}

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

Table-4.13: Variations in the mean values of water quality parameters under different treatments at 12th fortnight

Parameters \ Treatments	T_0	T_1	T_2	T_3
Water temperature (°C)	30.63±0.08^{a}	30.47±0.06^{a}	30.23±0.12^{a}	30.45±0.03^{a}
Transparency (cm)	31.67±0.67^{b}	34.33±0.33^{a}	32.33±0.88^{ab}	33.00±0.58^{ab}
DO (mg/l)	5.80±0.06^{a}	5.83±0.03^{a}	5.67±0.09^{ab}	5.53±0.03^{b}
pH	7.87±0.09^{a}	7.37±0.18^{bc}	7.73±0.12^{ab}	7.07±0.03^{c}
Alkalinity (mg/l)	114.32±1.45^{a}	116.21±2.67^{a}	114.81±1.53^{a}	115.25±0.54^{a}
Free CO_2 (mg/l)	3.45±0.03^{a}	3.30±0.01^{a}	3.38±0.03^{a}	3.46±0.03^{a}

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

4.4.1.2: Mean variations

The variations in the mean vales of different water quality parameters in different treatments by the total of all fortnights are presented in table 4.14 and fig. 4.1.

Water temperature

During the study period the mean values of water temperature ranged from 31.19±0.20 to 31.29±0.24°C. The minimum value was recorded in treatment T_3 whereas the maximum value was recorded in treatment T_0.

Water transparency

The mean value of water transparency varied from 32.28±0.32 to 32.83±0.40 cm. The minimum value was recorded in treatment T_2 whereas the maximum value was recorded in treatment T_1.

Dissolved Oxygen (DO)

The mean value of DO varied from 5.33±0.09 to 5.51±0.11 mg/l. The minimum value was recorded in treatment T_3 whereas the maximum value was recorded in treatment T_1.

Hydrogen ion concentration (pH)

The mean value of water pH varied from 7.18±0.03 to 7.38±0.05. The minimum value was recorded in treatment T_3 whereas the maximum value was recorded in treatment T_1.

Alkalinity

The mean value of total alkalinity varied from 113.61±0.74 to 114.58±0.67 mg/l. The minimum value was recorded in treatment T_1 whereas the maximum value was recorded in treatment T_0.

Free carbon-dioxide (CO_2)

The mean value of free CO_2 varied from 2.82±0.07 to 3.03±0.07. The minimum value was recorded in treatment T_1 whereas the maximum value was recorded in treatment T_0.

No significant difference was found among the treatments for mean values of water quality parameters.

Table 4.14: Variations in the mean values of water quality parameters under different treatments during study period

Parameters \ Treatments	T_0	T_1	T_2	T_3
Water temperature (°C)	31.29±0.24[a]	31.20±0.20[a]	31.24±0.21[a]	31.19±0.20[a]
Transparency (cm)	32.34±0.25[a]	32.83±0.40[a]	32.28±0.32[a]	32.44±0.24[a]
DO (mg/l)	5.39±0.12[a]	5.51±0.11[a]	5.34±0.12[a]	5.33±0.09[a]
pH	7.22±0.03[a]	7.38±0.05[a]	7.25±0.05[a]	7.18±0.03[a]
Alkalinity (mg/l)	114.58±0.67[a]	113.61±0.74[a]	114.05±0.87[a]	113.94±0.80[a]
Free CO_2 (mg/l)	3.03±0.07[a]	2.82±0.07[a]	3.00±0.07[a]	3.02±0.06[a]

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

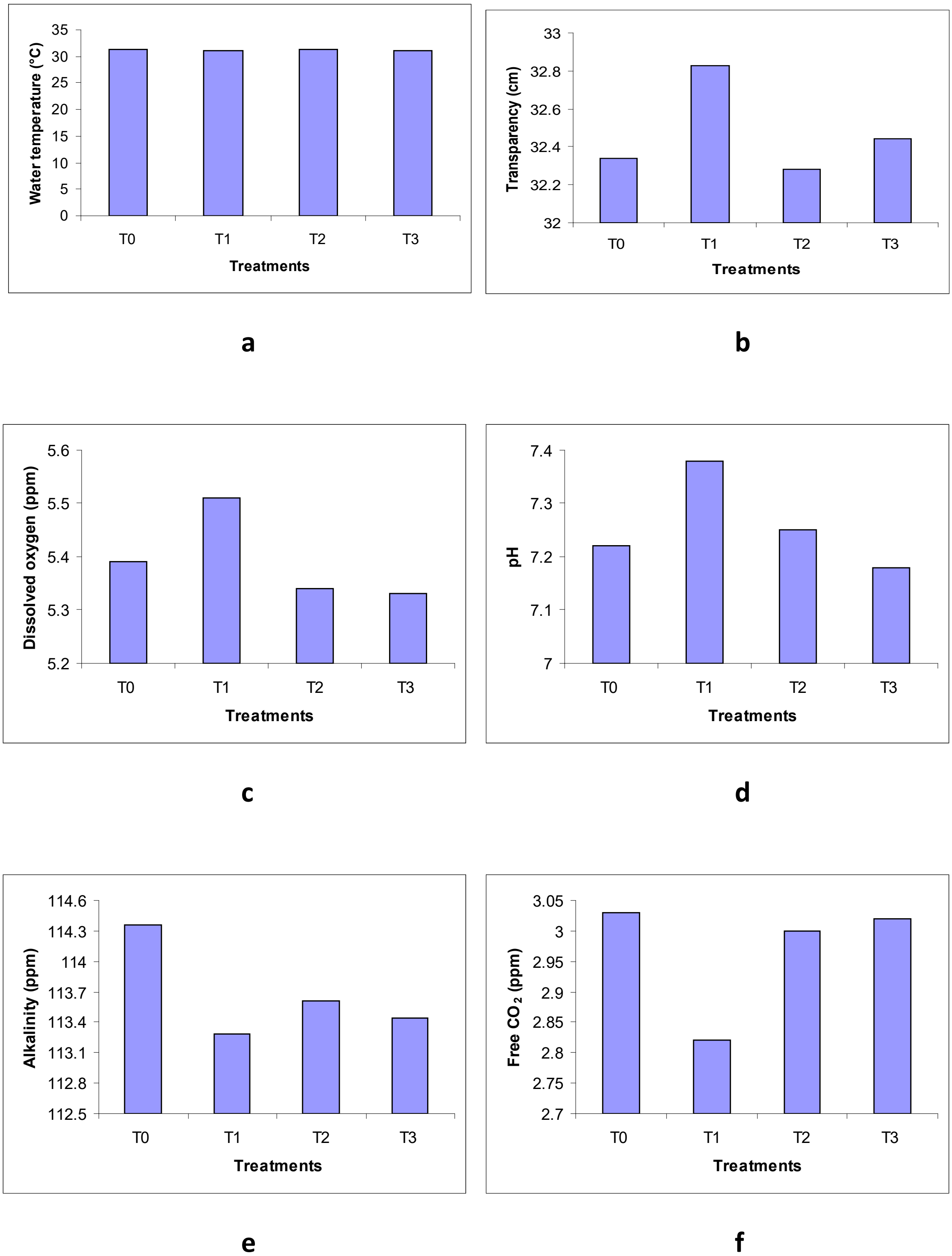


Fig. 4.1: Variations in the mean values of water quality parameters (a; Water temperature, b; transparency, c; DO, d; pH, e; alkalinity, f; free CO_2) under different treatments during study period.

4.4.2: Growth of fishes

4.4.2.1: Monthly variations

Specific growth rate (SGR, %, bwd^{-1})

The specific growth rate (%, bwd^{-1}) varied with *H. molitrix* from 0.30±0.01 (T_3 at 6th month) to 3.13±0.03 (T_0 at 1st month), *C. catla* from 0.28±0.01 (T_2 and T_3 at 6th month) to 2.49±0.09 (T_1 1st month), *L. rohita* from 0.23±0.04 (T_1 at 6th month) to 2.87±0.03 (T_0 at 1st month), *C. cirrhosus* from 0.31±0.05 (T_3 at 6th month) to 2.91±0.04 (T_0 1st month), *C. carpio* from 0.30±0.03 (T_3 at 6th month) to 2.70±0.03 (T_0 at 1st month), *C. idella* from 0.34±0.01 (T_0 6th month) to 3.15±0.06 (T_1 at 1st month) and *B. gonionotus* from 0.14±0.01 (T_2 at 6th month) to 3.01±0.06 (T_1 at 1st month) (Table 4.15 to 4.20).

Among the different species, the highest SGR was observed in *C. idella* as 3.15±0.06 %, bwd^{-1} and the lowest was in *B. gonionotus* as 0.14±0.01 %, bwd^{-1}.

The lowest combined SGR value was found as 0.30±0.03 (T_2 at 6th month) and the highest combined SGR was found as 2.62±0.17 (T_0 at 1st month). The highest SGR value was found in the month of April and the lowest value was found in the month of September for all the species.

Significant variation in SGR values with the treatments was found in all months except the 2nd month (May) for *C. carpio*, 2nd month (May) and 3rd month (June) for *C. idella*, 4th month (July), 5th month (August) and 6th month (September) for *C. cirrhosus* and 4th month (July) for *B. gonionotus*.

Table-4.15: Variations in the mean values of SGR (%, bwd^{-1}) of fishes under different treatments at 1st month (April)

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	$3.13±0.03^a$	$2.49±0.09^b$	$1.84±0.04^c$	$1.65±0.04^d$
C. catla	$1.77±0.05^b$	$2.49±0.09^a$	$1.95±0.05^b$	$1.83±0.07^b$
L. rohita	$2.87±0.03^a$	$1.91±0.07^b$	$1.42±0.06^c$	$1.36±0.04^c$
C. cirrhosus	$2.91±0.04^a$	$2.07±0.23^b$	$1.28±0.11^c$	$1.22±0.09^c$
C. carpio	$2.70±0.03^a$	$2.25±0.16^b$	$1.73±0.08^c$	$1.65±0.04^c$
C. idella	$2.63±0.26^b$	$3.15±0.06^a$	$2.51±0.06^b$	$2.48±0.04^b$
B. gonionotus	$2.36±0.32^b$	$3.01±0.06^a$	$1.59±0.12^c$	$1.59±0.07^c$
All species	$2.62±0.17^a$	$2.48±0.17^a$	$1.76±0.15^b$	$1.68±0.15^b$

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

Table-4.16: Variations in the mean values of SGR (%, bwd^{-1}) of fishes under different treatments at 2nd month (May)

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	$1.61±0.01^a$	$1.47±0.04^b$	$1.29±0.01^c$	$1.38±0.04^b$
C. catla	$2.07±0.07^a$	$1.49±0.04^b$	$1.38±0.04^b$	$1.43±0.05^b$
L. rohita	$1.55±0.02^a$	$1.35±0.06^b$	$1.20±0.04^c$	$1.18±0.01^c$
C. cirrhosus	$1.58±0.01^a$	$1.37±0.09^{ab}$	$1.19±0.06^b$	$1.18±0.08^b$
C. carpio	$1.52±0.02^a$	$1.46±0.12^a$	$1.35±0.05^a$	$1.39±0.03^a$
C. idella	$1.56±0.09^a$	$1.59±0.03^a$	$1.57±0.04^a$	$1.55±0.01^a$
B. gonionotus	$1.57±0.06^a$	$1.68±0.01^a$	$1.35±0.03^b$	$1.27±0.06^b$
All species	1.64±0.07a	1.49±0.04b	1.33±0.05c	1.34±0.05c

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

Table-4.17: Variations in the mean values of SGR (%, bwd^{-1}) of fishes under different treatments at 3rd month (June)

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	1.16 ± 0.003^{a}	1.13 ± 0.02^{ab}	1.08 ± 0.01^{b}	1.08 ± 0.02^{b}
C. catla	1.40 ± 0.01^{a}	1.15 ± 0.02^{b}	1.04 ± 0.01^{c}	1.03 ± 0.05^{c}
L. rohita	1.17 ± 0.02^{a}	1.08 ± 0.03^{b}	0.96 ± 0.03^{c}	1.00 ± 0.03^{bc}
C. cirrhosus	1.20 ± 0.01^{a}	1.11 ± 0.03^{b}	1.06 ± 0.02^{b}	1.07 ± 0.02^{b}
C. carpio	1.13 ± 0.003^{a}	1.10 ± 0.03^{ab}	1.06 ± 0.01^{b}	1.05 ± 0.01^{b}
C. idella	1.15 ± 0.01^{a}	1.16 ± 0.02^{a}	1.12 ± 0.003^{a}	1.12 ± 0.01^{a}
B. gonionotus	1.11 ± 0.003^{b}	1.33 ± 0.01^{a}	1.05 ± 0.01^{c}	0.97 ± 0.03^{d}
All species	1.19 ± 0.04^{a}	1.15 ± 0.03^{a}	1.05 ± 0.02^{b}	1.05 ± 0.02^{b}

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

Table-4.18: Variations in the mean values of SGR (%, bwd^{-1}) of fishes under different treatments at 4th month (July)

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	0.88 ± 0.01^{a}	0.82 ± 0.02^{b}	0.74 ± 0.02^{c}	0.76 ± 0.01^{c}
C. catla	1.35 ± 0.02^{a}	0.85 ± 0.01^{b}	0.71 ± 0.01^{c}	0.74 ± 0.01^{c}
L. rohita	0.83 ± 0.01^{a}	0.76 ± 0.01^{b}	0.70 ± 0.01^{c}	0.70 ± 0.03^{c}
C. cirrhosus	0.83 ± 0.003^{a}	0.82 ± 0.02^{a}	0.81 ± 0.03^{a}	0.85 ± 0.01^{a}
C. carpio	0.89 ± 0.01^{a}	0.82 ± 0.03^{b}	0.75 ± 0.01^{b}	0.75 ± 0.03^{b}
C. idella	0.83 ± 0.02^{ab}	0.88 ± 0.03^{a}	0.79 ± 0.01^{b}	0.79 ± 0.01^{b}
B. gonionotus	0.76 ± 0.02^{a}	0.81 ± 0.05^{a}	0.70 ± 0.02^{a}	0.69 ± 0.08^{a}
All species	0.91 ± 0.08^{a}	0.82 ± 0.01^{b}	0.74 ± 0.02^{c}	0.75 ± 0.02^{c}

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

Table-4.19: Variations in the mean values of SGR (%, bwd^{-1}) of fishes under different treatments at 5th month (August)

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	$0.58{\pm}0.01^{a}$	$0.54{\pm}0.02^{ab}$	$0.50{\pm}0.02^{bc}$	$0.47{\pm}0.01^{c}$
C. catla	$0.74{\pm}0.01^{a}$	$0.51{\pm}0.01^{b}$	$0.43{\pm}0.01^{c}$	$0.44{\pm}0.02^{c}$
L. rohita	$0.48{\pm}0.01^{a}$	$0.38{\pm}0.02^{b}$	$0.49{\pm}0.03^{a}$	$0.49{\pm}0.01^{a}$
C. cirrhosus	$0.53{\pm}0.01^{a}$	$0.52{\pm}0.01^{a}$	$0.57{\pm}0.02^{a}$	$0.57{\pm}0.03^{a}$
C. carpio	$0.56{\pm}0.01^{a}$	$0.52{\pm}0.01^{b}$	$0.48{\pm}0.01^{c}$	$0.46{\pm}0.01^{c}$
C. idella	$0.46{\pm}0.01^{b}$	$0.56{\pm}0.02^{a}$	$0.49{\pm}0.01^{b}$	$0.48{\pm}0.03^{b}$
B. gonionotus	$0.35{\pm}0.01^{b}$	$0.50{\pm}0.03^{a}$	$0.30{\pm}0.04^{b}$	$0.34{\pm}0.01^{b}$
All species	$0.53{\pm}0.05^{a}$	$0.50{\pm}0.02^{a}$	$0.47{\pm}0.03^{b}$	$0.46{\pm}0.08^{b}$

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.20: Variations in the mean values of SGR (%, bwd^{-1}) of fishes under different treatments at 6th month (September)

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	$0.40{\pm}0.01^{a}$	$0.40{\pm}0.01^{a}$	$0.32{\pm}0.01^{b}$	$0.30{\pm}0.01^{b}$
C. catla	$0.54{\pm}0.01^{a}$	$0.37{\pm}0.02^{b}$	$0.28{\pm}0.01^{c}$	$0.28{\pm}0.01^{c}$
L. rohita	$0.35{\pm}0.01^{a}$	$0.23{\pm}0.04^{c}$	$0.26{\pm}0.02^{bc}$	$0.33{\pm}0.01^{ab}$
C. cirrhosus	$0.37{\pm}0.003^{a}$	$0.38{\pm}0.01^{a}$	$0.38{\pm}0.01^{a}$	$0.31{\pm}0.05^{a}$
C. carpio	$0.40{\pm}0.01^{a}$	$0.38{\pm}0.01^{a}$	$0.36{\pm}0.02^{a}$	$0.30{\pm}0.003^{b}$
C. idella	$0.34{\pm}0.01^{b}$	$0.42{\pm}0.03^{a}$	$0.37{\pm}0.01^{ab}$	$0.40{\pm}0.01^{ab}$
B. gonionotus	$0.27{\pm}0.01^{b}$	$0.37{\pm}0.03^{a}$	$0.14{\pm}0.01^{c}$	$0.25{\pm}0.02^{b}$
All species	$0.38{\pm}0.03^{a}$	$0.36{\pm}0.02^{a}$	$0.30{\pm}0.03^{a}$	$0.31{\pm}0.02^{a}$

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Monthly weight gain (g/month)

The weight gain (g/month) varied with *H. molitrix* from 28.67±0.67 g (T_3 at 6th month) to 109.67±2.03 g (T_0 at 4th month), *C. catla* from 28.33±1.20g (T_3 at 6th month) to 154.33±3.84 g (T_0 at 4th month), *L. rohita* from 19.33±1.45 g (T_2 at 6th month) to 90.67±1.20 g (T_0 at 3rd month), *C. cirrhosus* from 22.67±3.33 g (T_3 at 6th month) to 90.00±0.58 g (T_0 at 3rd month), *C. carpio* from 29.67±0.33 (T_3 at 6th month) to 96.00±1.53 g (T_0 at 4th month), *C. idella* from 53.33±0.88 (T_2 at 6th month) to 111.33±4.37 g (T_1 at 3rd month) and *B. gonionotus* from 4.67±0.33 (T_2 at 6th month) to 50.00±0.58 g (T_1 at 3rd month) (Table 4.21 to 4.26).

Among the different species, the highest monthly weight gain was observed in *C. catla* as 154.33±3.84 g and the lowest was in *B. gonionotus* as 4.67±0.33 g.

The lowest combined weight gain value was found as 29.10±5.66 (T_2 at 6th month) and the highest combined weight was found as 94.52±13.75 (T_0 at 4th month). The highest weight gain was found in the month of July and the lowest value was found in the month of September for all the species.

Significant variation was found in all months for all the species except the 2nd month (May) and 6th month (September) for *C. idella*.

Table-4.21: Variations in the mean weight gain (g/month) of fishes under different treatments at 1st month (April)

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	96.33±1.45^{a}	69.00±3.46^{b}	45.67±1.45^{c}	39.67±1.20^{c}
C. catla	45.00±1.73^{b}	71.00±3.61^{a}	51.00±1.73^{b}	47.00±2.31^{b}
L. rohita	78.00±1.15^{a}	44.00±2.00^{b}	30.33±1.45^{c}	28.67±0.88^{c}
C. cirrhosus	75.33±1.45^{a}	47.00±7.00^{b}	25.33±2.60^{c}	24.00±2.00^{c}
C. carpio	78.67±1.45^{a}	61.00±6.08^{b}	43.00±2.65^{c}	40.33±1.20^{c}
C. idella	79.00±11.27^{b}	102.33±2.96^{a}	73.00±2.65^{b}	71.67±1.67^{b}
B. gonionotus	26.33±5.04^{b}	36.67±1.20^{a}	15.33±1.45^{c}	15.33±0.88^{c}
All species	68.38±9.07^{a}	61.57±8.38^{ab}	40.52±7.18^{b}	38.10±6.93^{b}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.22: Variations in the mean weight gain (g/month) of fishes under different treatments at 2nd month (May)

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	98.67±0.88^{a}	73.00±4.36^{b}	50.67±0.33^{c}	52.33±1.33^{c}
C. catla	93.67±2.73^{a}	76.00±4.36^{b}	59.00±1.15^{c}	59.33±2.33^{c}
L. rohita	80.00±0.58^{a}	50.67±3.48^{b}	37.67±0.88^{c}	36.33±0.33^{c}
C. cirrhosus	78.67±1.45^{a}	52.00±7.81^{b}	34.00±1.00^{c}	33.00±1.73^{c}
C. carpio	82.00±1.15^{a}	69.00±10.82^{ab}	53.00±1.00^{b}	53.33±1.20^{b}
C. idella	87.00±13.08^{a}	102.33±4.48^{a}	82.67±0.88^{a}	80.67±0.67^{a}
B. gonionotus	31.00±3.51^{b}	40.33±0.88^{a}	20.00±0.58^{c}	18.67±0.67^{c}
All species	78.72±8.42^{a}	66.19±7.82^{b}	48.14±7.62^{c}	47.67±7.66^{c}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.23: Variations in the mean weight gain (g/month) of fishes under different treatments at 3rd month (June)

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	107.33 ± 1.20^{a}	83.00 ± 5.29^{b}	60.33 ± 0.33^{c}	59.00 ± 1.15^{c}
C. catla	105.67 ± 1.20^{a}	87.00 ± 5.20^{b}	64.00 ± 1.15^{c}	61.67 ± 2.33^{c}
L. rohita	90.67 ± 1.20^{a}	58.33 ± 2.19^{b}	41.67 ± 1.76^{c}	42.67 ± 1.45^{c}
C. cirrhosus	90.00 ± 0.58^{a}	61.00 ± 7.00^{b}	42.33 ± 0.33^{c}	42.00 ± 1.00^{c}
C. carpio	90.67 ± 1.20^{a}	76.00 ± 8.89^{a}	59.33 ± 0.33^{b}	58.33 ± 0.88^{b}
C. idella	97.00 ± 12.29^{ab}	111.33 ± 4.37^{a}	88.33 ± 0.88^{c}	87.00 ± 1.00^{c}
B. gonionotus	32.33 ± 3.38^{b}	50.00 ± 0.58^{a}	22.33 ± 0.88^{c}	20.00 ± 0.58^{c}
All species	87.67 ± 9.62^{a}	75.24 ± 7.91^{b}	54.05 ± 7.93^{c}	52.95 ± 7.89^{c}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.24: Variations in the mean weight gain (g/month) of fishes under different treatments at 4th month (July)

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	109.67 ± 2.03^{a}	80.33 ± 6.17^{b}	54.00 ± 1.15^{c}	54.33 ± 1.20^{c}
C. catla	154.33 ± 3.84^{a}	85.67 ± 3.71^{b}	56.33 ± 0.67^{c}	57.33 ± 0.88^{c}
L. rohita	86.67 ± 0.88^{a}	54.00 ± 2.00^{b}	39.00 ± 0.58^{c}	38.33 ± 1.33^{c}
C. cirrhosus	84.33 ± 1.45^{a}	59.00 ± 5.13^{b}	43.00 ± 2.08^{c}	44.33 ± 0.33^{c}
C. carpio	96.00 ± 1.53^{a}	74.00 ± 3.61^{b}	55.33 ± 1.45^{c}	54.33 ± 1.86^{c}
C. idella	99.00 ± 10.58^{ab}	107.00 ± 5.13^{a}	82.00 ± 2.31^{c}	81.67 ± 1.67^{c}
B. gonionotus	31.67 ± 3.53^{a}	38.67 ± 0.67^{a}	19.33 ± 1.33^{b}	18.00 ± 2.08^{b}
All species	94.52 ± 13.75^{a}	71.24 ± 8.57^{b}	49.86 ± 7.27^{c}	49.76 ± 7.38^{c}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.25: Variations in the mean weight gain (g/month) of fishes under different treatments at 5th month (August)

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	90.67±1.20[a]	65.00±5.51[b]	44.33±2.33[c]	40.33±1.20[c]
C. catla	114.67±3.18[a]	63.00±3.61[b]	40.33±0.88[c]	40.67±1.67[c]
L. rohita	60.33±0.88[a]	32.67±2.91[b]	32.33±2.19[b]	32.00±1.15[b]
C. cirrhosus	65.67±1.45[a]	46.33±5.04[b]	37.00±1.53[b]	36.67±2.03[b]
C. carpio	75.00±2.08[a]	58.33±3.93[b]	42.67±1.20[c]	40.00±1.15[c]
C. idella	72.00±1.00[ab]	79.67±10.90[a]	61.33±0.67[ab]	60.00±2.52[b]
B. gonionotus	21.33±0.88[a]	24.00±3.21[a]	9.67±1.20[b]	10.33±0.33[b]
All species	71.38±10.82[a]	52.71±7.37[b]	38.24±5.87[c]	37.14±5.56[c]

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.26: Variations in the mean weight gain (g/month) of fishes under different treatments at 6th month (September)

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	72.00±1.15[a]	55.33±5.49[b]	32.00±1.00[c]	28.67±0.67[c]
C. catla	101.33±3.53[a]	52.33±5.90[b]	29.67±1.67[c]	28.33±1.20[c]
L. rohita	49.33±1.20[a]	21.33±4.67[b]	19.33±1.45[b]	24.67±0.67[b]
C. cirrhosus	52.00±1.15[a]	39.33±5.24[b]	28.00±1.53[c]	22.67±3.33[c]
C. carpio	61.33±1.86[a]	48.67±4.41[b]	36.67±2.19[c]	29.67±0.33[c]
C. idella	60.33±0.88[a]	68.33±11.22[a]	53.33±0.88[a]	56.00±2.08[a]
B. gonionotus	17.67±0.67[a]	20.00±3.21[a]	4.67±0.33[b]	8.33±0.88[b]
All species	59.14±9.54[a]	43.62±6.77[b]	29.10±5.66[c]	28.33±5.37[c]

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

4.4.2.2: Mean variations

Variations in the mean values of growth parameters of fishes under different treatments are shown in table 4.27 to 4.31, fig. 4.2 to 4.4 and plate 4.4.

SGR (%, bwd^{-1})

The specific growth rate (SGR, %, bwd^{-1}) varied with *H. molitrix* from 0.94±0.21 (T_3) to 1.29±0.41 (T_0), *C. catla* from 0.96±0.24 g (T_3) to 1.31±0.24 (T_0), *L. rohita* from 0.84±0.16 (T_3) to 1.21±0.38 (T_0), *C. cirrhosus* from 0.87±0.15 (T_3) to 1.24±0.38 (T_0), *C. carpio* from 0.93±0.22 (T_3) to 1.20±0.34 (T_0), *C. idella* from 1.03±0.23 (T_0) to 1.31±0.31 (T_1) and *B. gonionotus* from 0.85±0.21 (T_3) to 1.05±0.25 (T_1).

Among the different species the highest SGR was observed as 1.31±0.31 %, bwd^{-1} in *C. idella* and the lowest was in *L. rohita* as 0.84±0.16 %, bwd^{-1}.

The lowest combined SGR (%, bwd^{-1}) value was found as 0.93±0.03 (T_3) and the highest combined SGR (%, bwd^{-1}) found as 1.17±0.05 (T_0).

Significant difference was found among the treatments for the mean values of SGR for all the species.

Weight gain (g/month)

Mean weight gain (g/month) varied with *H. molitrix* from 45.72±4.66 g (T_3) to 95.78±5.56g (T_0), *C. catla* from 49.06±5.28 g (T_3) to 102.45±14.41g (T_0), *L. rohita* from 33.39±3.30 g (T_2) to 74.17±6.55g (T_0), *C. cirrhosus* from 33.78±3.68 g (T_3) to 74.33±5.59 g (T_0), *C. carpio* from 46.00±4.51 g (T_3) to 80.61±4.99 g (T_0), *C. idella* from 72.84±5.13 g (T_3) to 95.17±6.99 g (T_1) and *B. gonionotus* from 15.11±1.95 g (T_3) to 34.95±4.53 g (T_1).

Among the different species the highest weight gain was observed as 102.45±14.41 g in *C. catla* and the lowest was in *B. gonionotus* as 15.11±1.95 g.

Considering all the species the lowest mean weight gain was found as 42.33±6.71 g (T_3) and the highest weight gain was found as 76.64±9.24 g (T_0).

Significant difference was found among the treatments for the mean values of weight gain for all the species.

Final weight (g)

The mean final weight (g) varied with *H. molitrix* from 336.33±2.03 (T_3) to 636.67±5.61 g (T_0), *C. catla* from 358.33±4.41 (T_3) to 678.67±12.57 g (T_0), *L. rohita* from 257.33±5.04 (T_2) to 502.00±2.08 g (T_0), *C. cirrhosus* from 256.67±1.76 (T_3) to 500.00±7.23 g (T_0), *C. carpio* from 339.00±3.79 (T_3) to 546.67±8.69 g (T_0), *C. idella* from 502.00±4.16 (T_3) to 620.33±18.02 g (T_1) and *B. gonionotus* from 115.67±2.60 (T_3) to 229.67±2.67 g (T_1).

Among the different species the highest final weight was observed as 678.67±12.57 g in *C. catla* and the lowest was in *B. gonionotus* as 115.67±2.60 g.

Considering all the species the lowest mean final weight was found as 2167.67±17.31 g (T_3) and the highest final weight was 3629.34±19.52 g (T_0) for all the species.

Significant difference was found among the treatments for the mean values of final weight for all the species.

Survival rate (%)

The survival rate (%) varied with *H. molitrix* from 81.33±1.20 (T_2) to 84.33±2.03% (T_0), *C. catla* from 75.33±1.59 (T_2) to 81.00±1.73% (T_0), *L. rohita* from 77.67±1.45 (T_3) to 81.33±0.88% (T_0), *C. cirrhosus* from 67.50±1.44 (T_2) to 80.33±2.91% (T_0), *C. carpio* from 78.00±1.73% (T_2) to 86.33±2.40% (T_0), *C. idella* from 73.00±1.15 (T_0) to 83.00±1.15% (T_1) and *B. gonionotus* from 70.33±1.45 (T_0) to 78.67±0.67% (T_1).

Among the species the highest survival rate was observed as 86.33±2.40% in *C. carpio* and the lowest was in *C. cirrhosus* as 67.50±1.44%.

The lowest mean survival rate was found as 76.33±1.74% g (T_2) and the highest final weight as 79.52±2.20% (T_0) for all the species.

Significant difference was found among the treatments for the mean values of survival rate of all the species except *H. molitrix* and *L. rohita*.

Yield (Kg/ha/6 months)

The yield (Kg/ha/6 months) varied with *H. molitrix* from 636.00±3.79 (T_3) to 1250.00±14.43 (T_0), *C. catla* from 186.67±2.03 (T_3) to 426.33±8.41 (T_0), *L. rohita* from 479.33±924 (T_2) to 992.00±4.16 (T_0), *C. cirrhosus* from 269.67±1.76 (T_3) to 555.00±7.81 (T_0), *C. carpio* from 226.00±2.65 (T_3) to 385.00±6.03 (T_0), *C. idella* from 527.00±4.16 (T_3) to 603.67±71.64 (T_1) and *B. gonionotus* from 214.33±4.63 (T_3) to 375.67±41.34 (T_1).

Among the different species the highest yield was observed as 1250.00±14.43 kg/ha/6 months in *H. molitrix* and the lowest was in *C. catla* as 186.67±2.03 kg/ha/6 months.

The lowest total yield (Kg/ha/6 months) was found as 2541.00±0.67 (T_3) and the highest total yield was found as 4403.51±0.88 (T_0). Significant difference was found among the treatments.

Significant difference was found among the treatments for the mean values of yield for all the species.

Table-4.27: Variations in the mean SGR (%, bwd^{-1}) of fishes under different treatments during the study period

Species \ Treatments	T_0	T_1	T_2	T_3
H. molitrix	1.29±0.41^a	1.14±0.31^a	0.96±0.23^b	0.94±0.21^b
C. catla	1.31±0.24^a	1.14±0.32^a	0.97±0.26^b	0.96±0.24^b
L. rohita	1.21±0.38^a	0.95±0.26^b	0.84±0.18^b	0.84±0.16^b
C. cirrhosus	1.24±0.38^a	1.05±0.25^{ab}	0.88±0.15^b	0.87±0.15^b
C. carpio	1.20±0.34^a	1.09±0.28^{ab}	0.96±0.22^b	0.93±0.22^b
C. idella	1.03±0.23^b	1.31±0.31^a	1.14±0.33^b	1.10±0.32^b
B. gonionotus	0.93±0.21^{ab}	1.05±0.25^a	0.86±0.28^b	0.85±0.21^b
All species	1.17±0.05^a	1.10±0.04^{ab}	0.94±0.04^b	0.93±0.03^b

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.28: Variations in the mean weight gain (g/month) of fishes under different treatments during the study period.

Species \ Treatments	T_0	T_1	T_2	T_3
H. molitrix	95.78±5.56^a	70.94±4.17^b	47.83±3.96^c	45.72±4.66^c
C. catla	102.45±14.41^a	72.50±5.46^b	50.06±5.24^b	49.06±5.28^b
L. rohita	74.17±6.55^a	43.50±5.75^b	33.39±3.30^b	33.78±2.70^b
C. cirrhosus	74.33±5.59^a	50.78±3.36^b	34.94±2.97^c	33.78±3.68^c
C. carpio	80.61±4.99^a	64.50±4.26^b	48.33±3.60^c	46.00±4.51^c
C. idella	82.39±6.10^{ab}	95.17±6.99^a	73.44±5.57^b	72.84±5.13^b
B. gonionotus	26.72±2.49^a	34.95±4.53^a	15.22±2.78^b	15.11±1.95^b
All species	76.64±9.24^a	61.76±7.71^b	43.32±6.83^c	42.33±6.71^c

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.29: Variations in the mean final weight (g) of fishes under different treatments during the study period.

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	636.67±5.61^{a}	487.67±30.21^{b}	349.00±4.04^{c}	336.33±2.03^{c}
C. catla	678.67±12.57^{a}	499.00±26.10^{b}	364.33±2.91^{c}	358.33±4.41^{c}
L. rohita	502.00±2.08^{a}	318.00±16.29^{b}	257.33±5.04^{c}	259.67±3.48^{c}
C. cirrhosus	500.00±7.23^{a}	358.67±36.86^{b}	263.67±6.06^{c}	256.67±1.76^{c}
C. carpio	546.67±8.69^{a}	450.00±37.63^{b}	353.00±4.73^{c}	339.00±3.79^{c}
C. idella	575.00±68.46^{b}	620.33±18.02^{a}	505.67±5.78^{b}	502.00±4.16^{b}
B. gonionotus	190.33±20.96^{b}	229.67±2.67^{a}	116.33±4.33^{c}	115.67±2.60^{c}
All species	3629.34±19.52^{a}	2963.34±21.20^{b}	2209.33±14.25^{c}	2167.67±17.31^{c}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.30: Variations in the mean survival rate (%) of fishes under different treatments during the study period.

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	84.33±2.03^{a}	82.67±2.60^{a}	81.33±1.20^{a}	82.67±1.20^{a}
C. catla	81.00±1.73^{a}	79.33±2.33^{a}	75.33±1.59^{b}	75.33±2.03^{ab}
L. rohita	81.33±0.88^{a}	79.33±2.33^{a}	78.00±1.73^{a}	77.67±1.45^{a}
C. cirrhosus	80.33±2.91^{a}	74.50±3.91^{ab}	67.50±1.44^{b}	68.50±0.76^{b}
C. carpio	86.33±2.40^{a}	79.00±3.06^{b}	78.00±1.73^{b}	78.33±0.88^{b}
C. idella	73.00±1.15^{b}	83.00±1.15^{a}	80.00±6.56^{a}	81.33±1.76^{a}
B. gonionotus	70.33±1.45^{b}	78.67±0.67^{a}	74.17±3.63^{a}	76.33±1.45^{a}
All species	79.52±2.20^{a}	79.50±1.07^{a}	76.33±1.74^{a}	77.17±1.75^{a}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-4.31: Variations in the mean yield (kg/ha) of fishes under different treatments during the study period.

Treatments / Species	T_0	T_1	T_2	T_3
H. molitrix	1250.00±14.43^a (28.39%)	953.33±59.27^b (25.94%)	663.67±6.12^c (25.59%)	636.00±3.79^c (25.03%)
C. catla	426.33±8.41^a (9.68%)	295.67±15.38^b (10.86%)	190.00±2.31^c (7.33%)	186.67±2.03^c (7.35%)
L. rohita	992.00±4.16^a (20.26%)	628.33±32.31^b (17.10%)	479.33±9.24^c (18.48%)	481.33±6.39^c (18.94%)
C. cirrhosus	555.00±7.81^a (12.60%)	398.33±40.92^b (10.84%)	278.67±4.98^c (10.74%)	269.67±1.76^c (10.61%)
C. carpio	385.00±6.03^a (8.74%)	317.00±26.66^b (8.63%)	235.33±2.96^c (9.07%)	226.00±2.65^c (8.89%)
C. idella	566.10±23.36^b (12.86%)	603.67±71.64^a (16.42%)	531.00±6.11^b (20.47%)	527.00±4.16^b (20.74%)
B. gonionotus	329.08±5.37^b (7.47%)	375.67±41.34^a (10.22%)	215.67±8.09^c (8.32%)	214.33±4.63^c (8.43%)
Total yield (Kg/ha/6 months)	4403.51±0.88^a	3675.33±0.58^b	2593.67±0.11^c	2541.00±0.67^d
Total yield (Kg/ha/yr)	8807.02±0.69^a	7350.66±0.46^b	5187.34±0.23^c	5082.00±0.41^d

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Values in the parentheses means % contribution by individual species to total fish yield under respective treatment.

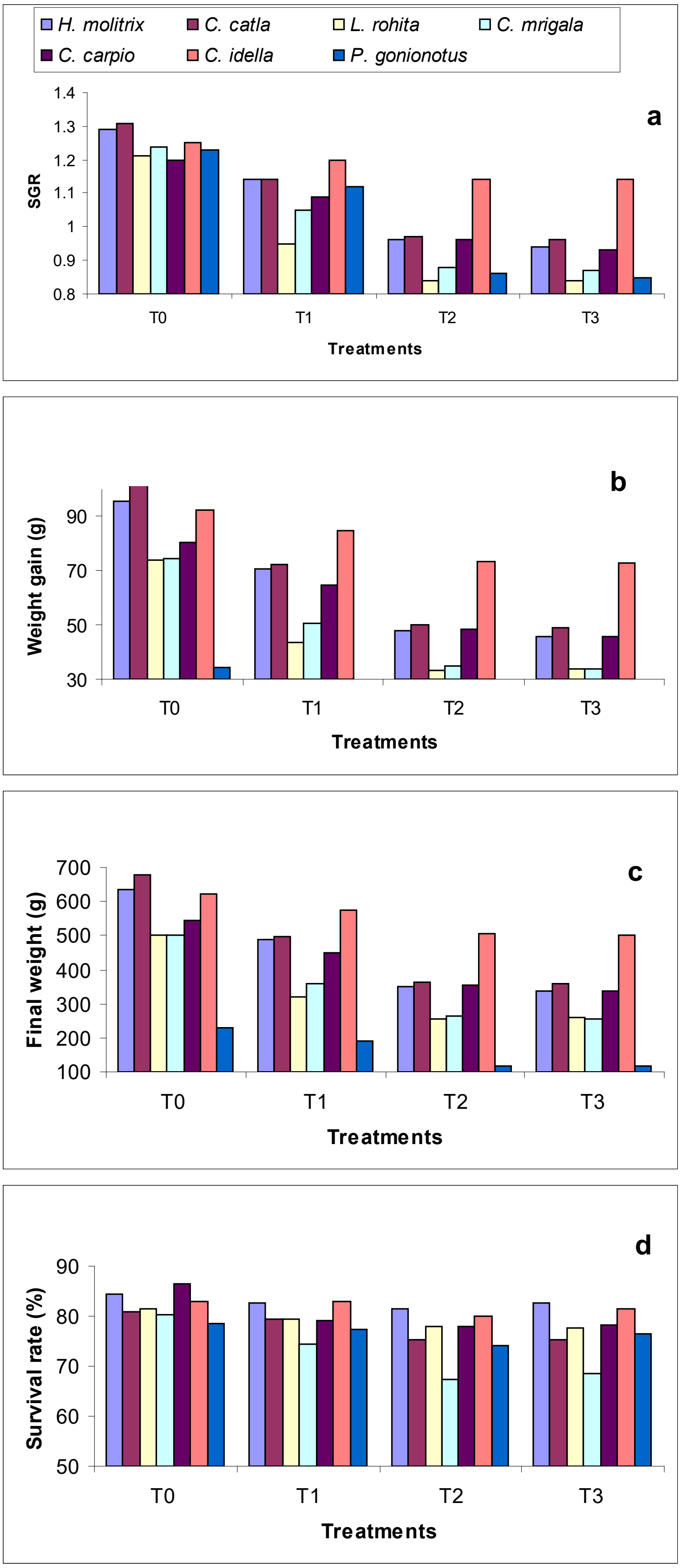


Fig. 4.2: Variations in the mean values of different growth parameters under different treatments during the study period: a; SGR (%, bwd^{-1}), b; weight gain (g/month), c; final weight (g) and d; survival rate (%)

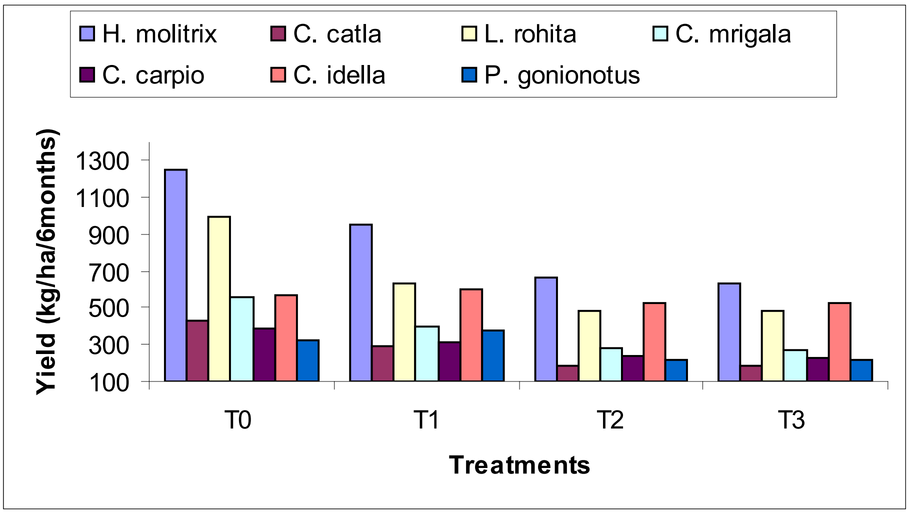


Fig. 4.3: Mean values of individual fish yield under different treatments

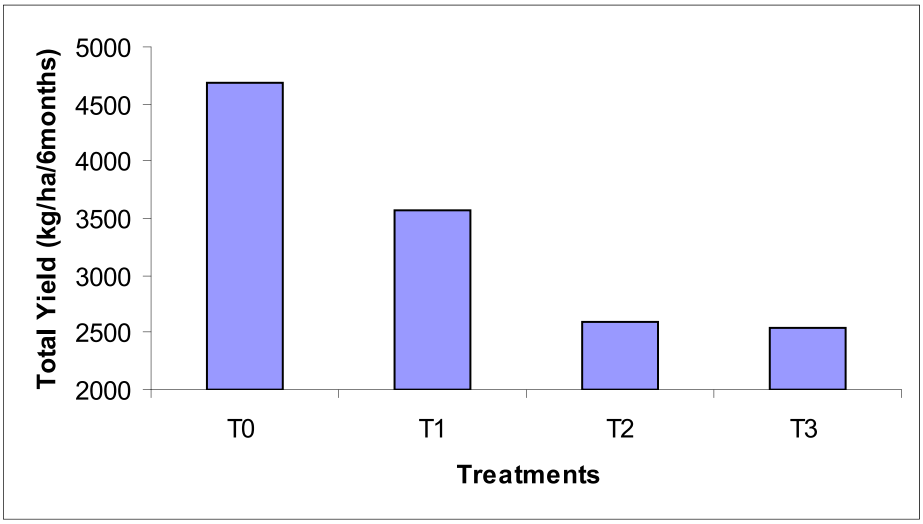


Fig. 4.4: Mean values of total fish yield under different treatments

Plate 4.4: Harvesting of fishes.

4.3.3: Economics

The economics of fish farming under different treatments are presented in table 4.32 and fig. 4.5.

Total cost significantly varied from 123430.50±0.00 (T_1, T_2, T_3) to 235930.50±0.00 BDT/ha/6 months (T_0). Gross benefit significantly varied from 235068.40±1965.31 (T_3) to 418376.85±5125.59 Tk/ha/6 months (T_0). Net benefit significantly varied from 111639.90±2056.87 (T_3) to 206744.85±3221.73 Tk/ha/6 months (T_1). The Net profit margin significantly varied from 77.21±2.40 (T_0) to 167.20±18.77% (T_1). The CBR significantly varied from 0.77±0.02 (T_0) to 1.67±0.18 (T_1).

Table 4.32: Economics of fish farming under different treatments during study period

Components \ Treatments	T_0	T_1	T_2	T_3
Lease value (Tk.)	40000.00±0.00^a (16.95%)	40000.00±0.00^a (32.41%)	40000.00±0.00^a (32.41%)	40000.00±0.00^a (32.41%)
Pond preparation (Tk.)	10550.00±0.00^a (4.47%)	10550.00±0.00^a (8.55%)	10550.00±0.00^a (8.55%)	10550.00±0.00^a (8.55%)
Fertilizer (Tk.)	25400.00±0.00^a (10.77%)	25400.00±0.00^a (20.58%)	25400.00±0.00^a (20.58%)	25400.00±0.00^a (20.58%)
Fish seed (Tk.)	32480.50±0.00^a (13.77%)	32480.50±0.00^a (26.31%)	32480.50±0.00^a (26.31%)	32480.50±0.00^a (26.31%)
Feed (Tk.)	112500.00±0.00^a (47.68%)	0.00±0.00^b (0.00%)	0.00±0.00^b (0.00%)	0.00±0.00^b (0.00%)
Harvesting cost (Tk.)	15000.00±0.00^a (6.36%)	15000.00±0.00^a (12.15%)	15000.00±0.00^a (12.15%)	15000.00±0.00^a (12.15%)
Total cost (Tk.)	235930.50±0.00^a	123430.50±0.00^b	123430.50±0.00^b	123430.50±0.00^b
Gross benefit (Tk.)	418376.85±5125.59^a	330175.35±2155.32^b	239526.95±2335.84^c	235068.40±1965.31^c
Net benefit (Tk.)	182446.35±3265.00^b	206744.85±3221.73^a	116096.45±3554.84^c	111639.90±2056.87^c
Net profit margin (%)	77.21±2.40^b	167.20±18.77^a	94.38±2.91^{ab}	90.25±1.73^{ab}
CBR	0.77±0.02^b	1.67±0.18^a	0.94±0.03^{ab}	0.90±0.02^{ab}

Figures bearing common letter(s) in a row as superscript do not differ significantly (P <0.05)
% of total cost in parentheses

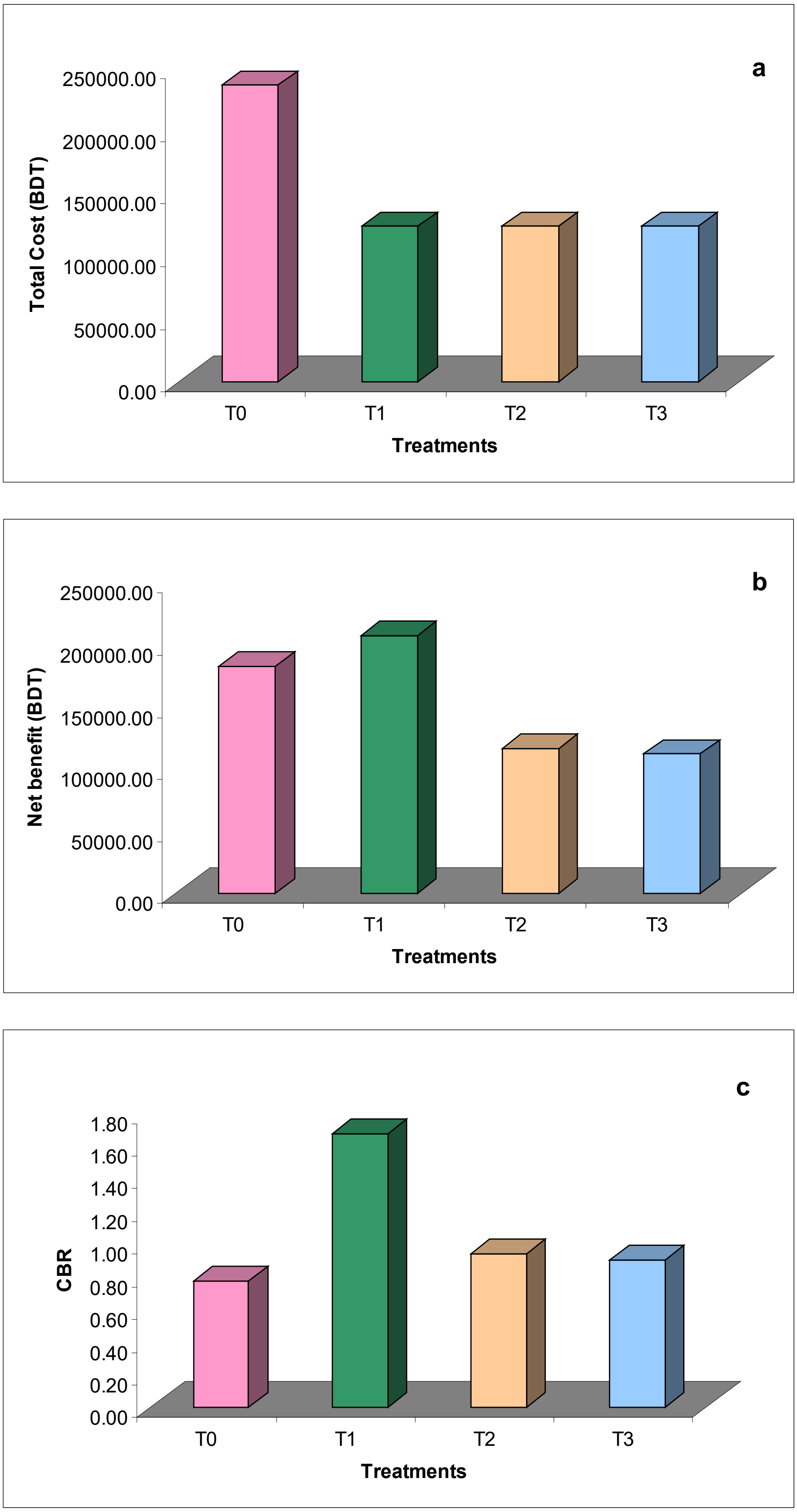


Fig. 4.5: Economics of fish farming under different treatments: a; total cost (BDT), b; net benefit (BDT) and c; CBR

4.4: Discussion

4.4.1: Water quality parameters

Water quality parameters play an important role on the growth and production of fish and other aquatic organisms. The suitable water quality parameters are prerequisites for a healthy aquatic environment and for the production of sufficient fish food organisms. The primary productivity of a water body depends on the physical, chemical and other factors of the environment (Rahman, 1992).

Fortnightly variations

Water temperature

The temperature of water has extremely important ecological consequences. Temperature exerts a major influence on aquatic organisms with respect to selection and level of activity of the organisms. In general, increasing water temperature results in greater biological activity and more rapid growth. All aquatic organisms have preferred temperature in which they can survive and reproduce optimally. Temperature is a regulator of the solubility of gases and minerals (solids). The solubility of important gases, such as oxygen and carbon dioxide increases as temperature decreases (Jhingran, 1975). In the present study water temperature varied from 29.58±0.03 to 32.23±0.08°c. Lower temperature (29.58±0.03) with treatment T_0 at 1^{st} fortnight (April 2011) might be due to spring season when air temperature was relatively low (Appendix-1). Higher water temperature (32.23±0.08°C) with treatment T_0 at 6^{th} fortnight (June, 2011) might be due to bright sunlight during study period (Appendix-1). The water temperature of the studied ponds increased towards first three months due to summer season and gradually decreased at the end of the study which was influenced by advent of winter season. Ferdoushi *et al*. (2008) recorded temperature range 23.6°C to 35.5°C, while working on carp polyculture for a period of five months (July to November) in Azolla fed pond. No significant difference was found among the treatments for the fortnightly values of temperature. Rahman *et al.* (1982) found pond water temperature varied from 26.06°C to 31.97°C that was almost similar to those obtained in the present study. Wahab *et al.* (1995) found that the suitable temperature range in BAU campus, Mymensingh was 27.2°C to 32.4°C. Islam *et al*. (1997) and Sharmin and Jewel (2008) also reported similar findings while working on carp polyculture.

Water transparency

Transparency is a measure of how clear the water is. It is important, because aquatic plants need sunlight for photosynthesis. The clearer the water, the deeper sunlight will penetrate. The water transparency acts as an index of productivity of a water body. The water transparency showed variation with sampling dates and it ranged from 30.00±0.58cm with treatment T_2 at 7th fortnight (July) to 35.00±0.00 cm with treatment T_1 at 1st fortnight (April). This higher value might be due to the available nutrient concentration resulting from basal dose of both organic and inorganic fertilization with the treatment.

In the present study, the lower value of the transparency in the month of July, 2011 might be due to higher turbidity causes by heavy rain fall in that month (Appendix-2). Significant variation was found at 1st, 10th and 12th fortnights among the treatments, these variations might be due to rainfall and / or nutrient concentrations. This observation is similar to the findings of Chowdhury and Mamun (2006) while working on the water quality analysis in two ponds in Khulna. According to Boyd (1990) secchi disc visibility about 30 to 45 cm means the water body productive, if it is not newly constructed or turbid due to rainfall or burrowing by fish or other organisms.

Dissolved oxygen (DO)

Dissolved oxygen (DO) content is probably the only most important water quality parameters in aquaculture. Prolonged exposure to low concentration of DO can be harmful for aquatic life (BAFRU, 1990). In the present study, DO content of water was observed between 4.90±0.06 mg/l with treatment T_2 at 6th fortnight (June) to 6.17±0.12 mg/l with the treatment T_1 at 10th fortnight (August). The lower value during month of June was probably due to high temperature, respiration and decomposition of organic matter. The maximum DO value was 6.17±0.12 mg/l (T_1 at 10th fortnight) due to advent of winter which agreed with Saha *et al.* (1971) while working on seasonal variations in water quality parameters in fish pond. Wahab *et al.* (1995) worked with carp polyculture in ponds and reported that DO concentration ranging from 5.0-7.0 mg/l is within the good productive range. DoF (1998) reported that the suitable DO of water body for fish culture would be 5-8 mg/l. So the result of the present study is more or less similar to the findings of the above authors. Significant variations were found at 6^{th}, 9^{th}, 11^{th} and 12^{th} fortnights among the treatments. Fortnightly variations might be due to fluctuation of temperature (Appendix-2) and treatments variation in the same fortnight might be decomposition of supplied feeds and weeds. These arguments are supported by Majhi *et al.* (2006) who worked with growth performance and production of organically cultured grass carp.

Hydrogen ion concentration (pH)

pH is defined as the relative degree of acidity or alkalinity in an environment. pH of water is one of the most important factor which has intense effect on the productivity of water body. There were no wide variations in pH values in the investigated ponds. The values of pH in the water ranged from 7.03±0.03 (T_3 at 6^{th} forthright) to 7.87±0.09 (T_0 at 12^{th} forthright). During the experimental period pH of the most ponds were slightly alkaline, which indicated a good pH condition for fish culture. Similar findings were found by Islam *et al.* (1997). Significant variation was found at 12^{th} fortnight among the treatments. According to Bergins (1949) in alkaline water pH value increases with the increase of carbonate because in alkaline water by the increased consumption of CO_2, cause the breaking of bicarbonate into free CO_2 and carbonate ($2HCO_3 = CO_2 + CO_3^{-2} + H_2O$). However the pH value in alkaline condition in pond water was supposed to be helpful for proper growth and development of fishes and aquatic organisms (Nikolsky, 1963; Huet, 1972, Jhingran, 1975).

Alkalinity

Alkalinity refers to the sum of the carbonate and bi-carbonate alkalinities. In case of aquatic productivity, the total alkalinity is also an important factor. Total alkalinity was found to range from 109.22±1.33 (T_3 at 1^{st} forthright) to 120.00±1.15 mg/l (T_0 at 9^{th} forthright). Welch (1952) and Huchinson (1957) reported that decrease in alkalinity might probably be caused by the break down of bicarbonate due to the photosynthetic activity of plants. The high value during the spring was possibly due to the low CO_2, low rainfall and evaporation of water, which causes an increase in alkalinity. Significant variations were found at 8th and 9th fortnights (July and August), among the treatments. It might be due to heavy rainfall (Appendix-1). Production of free CO_2 enhanced by high temperature agreed with Michael (1968) and Verma (1969). Alikhuni (1957) reported that total alkalinity more than 100 mg/l should be present in high productive water bodies. Haque *et al.* (2005) found the average total alkalinity values above 100 mg/l in their experiments while working on production and economic return of carp polyculture in farmers ponds.

Free carbon dioxide (CO_2)

The mean values of free carbon dioxide varied from 2.49±0.07 (T_1 at 4th forthright) to 3.46±0.03 mg/l (T_3 at 12th forthright). The lower value of free CO_2 content was obtained at the starting period of the experiment (May, 2011) when temperature and rainfall were relatively low (Appendix-1). Higher values of free CO_2 accelerated the rate of decomposition of organic matter by microbes, decrease of photosynthetic activity and high rate of respiration by benthic biota and microorganisms (Chowdhury *et al.,* 1992). Significant variation was found at 10th fortnight among the treatments. Higher value of CO_2 with treatment T_0 might be due to comparatively low intake of feed by fishes in rainy season. As a result wastage of supplied feed increased and decomposition took place at higher rate which ultimately increased the free CO_2 level with that treatment. The fluctuation of CO_2 value might be due to alteration in the rate of photosynthesis in ponds and oxygen consumption by fish and other decomposer microorganisms (Khan *et al*., 2009).

Mean variation

Water temperature

In the present study, the mean value of water temperature varied from 31.19±0.20 (T_3) to 31.29±0.24°C (T_0). The water temperature measured in different treatments throughout the experimental period were within the acceptable range for fish culture. PRISM-Bangladesh made a study on weed-based carp polyculture and recorded water temperature as 28.1 to 32°C (DWRP, 1996 and 1997). Ferdoushi *et al*. (2008) reported water temperature as 29.30±2.63°C to 29.60±2.47°C while working on aquatic floating macrophytes (Lemna and Azolla) in fish pond. Dewan *et al*. (1991) reported a temperature range of 30.20 to 34.0°C, while Wahab *et al*. (1996) recorded from 28.5 to 31.3°C in their experiment with carp polyculture. Water temperature of 25 to 32^0C is considered suitable for fish culture (Boyd and Zimmermann, 2000).

Water transparency

The mean value of water transparency in this study varied from 32.28±0.32 (T_2) to 32.83±0.40 cm (T_1). Banforth (1958) reported that transparency indicated the presence and absence of food particles and productivity of a water body, which was influenced by the suspended materials, silt and microorganisms. Rahman *et al*. (2006) found mean values of transparency ranging from 20.71 to 26.37°C while working with carp polyculture in seasonal ponds. Present finding has similarity with the findings of Azim *et al*. (1995) who found the transparency value as 36.2cm in weed based carp polyculture pond. Boyd (1982) also recommended the transparency between 30 to 45 cm as appropriate for fish culture.

Dissolved oxygen (DO)

The mean value of dissolved oxygen varied from 5.33±0.09 (T_3) to 5.51±0.11 (T_1) mg/l. More or less similar finding (4.15 mg/l) was made by Thy *et al*. (2004) in effluent plus water spinach treated pond. Chowdhury *et al*. (2008) reported the mean values of DO ranging from 6.29 to 6.64, while working with duckweed fed Nile tilapia culture in earthen ponds. Azim and Wahab (2003) recorded similar DO value that ranging from 4.1 to 5.25 mg/l in duckweed based carp polyculture pond. The suitable range of dissolved oxygen is 5-8 mg/l for fish culture (Boyd, 1998).

Hydrogen ion concentration (pH)

The mean value of pH varied from 7.18±0.03 (T_3) to 7.38±0.05 (T_1). Ferdoushi *et al*. (2008) recorded pH value as 7.53±0.034 in Azolla fed carp polyculture pond. Dewan *et al*. (1991) recorded the mean value of water pH ranged from 6.60-8.60 which is similar to the present study. Majhi *et al*. (2006) reported that the variation in pH was 7.5-8.2 of a Azolla fed pond in Meghalaya of North Eastern India. Hossain *et al*. (1997) also obtained a pH range of 6.7 to 8.3 in fish ponds. According to Swingle (1967), pH of 6.5 to 9 is suitable for fish culture. Large changes in pH can cause stress, poor growth and even death of the farmed animals (Wurts and Durborow, 1992). Kohinoor *et al*. (1998) also recorded the mean values of pH as 7.18±2.40 in ponds. In the present study the alkaline pH range in all treatments indicated good pH condition for biological production and fish culture.

Alkalinity

The recorded mean total alkalinity varied from 113.28±0.85 (T_1) to 114.36±0.72 (T_0) mg/l. Total alkalinity values depending upon the location, season, plankton population and nature of bottom deposits (Jhingran, 1991). Mitra *et al*. (1978) found alkalinity values results ranged from 100.00 to 162.00 mg/l in carp polyculture ponds which was relatively higher than the present study. It might be due to low dissolved oxygen content and more production of free CO_2 that enhanced by increasing of fish biomass which strongly supported by Michael (1968) and Verma (1969) while working with water quality parameters in fish ponds and tropical impoundments. Boyd (1982) advocated that the total alkalinity should be more than 20 ppm in fertilized ponds as production increases with the increase in total alkalinity. The suitable range of alkalinity in fish culture is found as 50 to 300 mg/l (Buttner, 1993). Mairs (1996) also stated that the total alkalinity of 40.0 mg/l or more to be productive than water bodies with lower alkalinity. So, the alkalinity values of the study ponds were found within the suitable range for fish farming.

Free carbon-dioxide

Results from the study indicated that the value of free CO_2 varied from 2.82±0.07 (T_1) to 3.03±0.07 mg/l (T_0). Comparatively higher value of CO_2 recorded in ponds used with conventional fish feed pond (T_0) might be due to higher fish biomass and decomposition of unused fish feed. Lower value of CO_2 recorded in Azolla fed pond (T_1) might be due to frequent supply of oxygen by aquatic macrophytes. This argument is strongly supported by Chowdhury *et al.* (2008) when they used duckweed as supplementary feed. The suitable range of free CO_2 for fish culture is ranged from 1.0 to 10.0 mg/l (Boyd, 1998). Wurts and Durbrow (1992) reported that the desirable range of CO_2 1-2 ppm for pond aquaculture.

4.4.2: Growth of fishes

Monthly variations

Specific growth rate (%, bwd^{-1})

The specific growth rate (%, bwd^{-1}) significantly varied with *H. molitrix* from 0.30±0.01 (T_3 at 6th month) to 3.13±0.03 (T_0 at 1st month), *C. catla* from 0.28±0.01 (T_2 and T_3 at 6th month) to 2.49±0.09 (T_1 1st month), *L. rohita* from 0.23±0.04 (T_1 at 6th month) to 2.87±0.03 (T_0 at 1st month), *C. cirrhosus* from 0.31±0.05 (T_3 at 6th month) to 2.91±0.04 (T_0 1st month), *C. carpio* from 0.30±0.03 (T_3 at 6th month) to 2.70±0.03 (T_3 at 3rd month), *C. idella* from 0.34±0.01 (T_0 6th month) to 3.15±0.06 (T_1 at 1st month) and *B. gonionotus* from 0.14±0.01 (T_2 at 6th month) to 3.01±0.06 (T_1 at 1st month). Among the species, the highest SGR was observed in *C. idella* as 3.15±0.06 % bwd^{-1} (T_1) and the lowest was in *B. gonionotus* as 0.14±0.01 %, bwd^{-1} (T_2). The result indicates that *C. idella* grows very fast at early stage as compared to other carp species if fed with Azolla. Majhi *et al*. (2006) found that grass carp fed with Azolla showed a higher growth performance at early stage. Results indicated that *B. gonionotus* grows slowly at winter, fed with grass.

Significant variation in SGR values with the treatments was found in all months except the 2nd month (May) for *C. carpio*, 2nd month (May) and 3rd month (June) for *C. idella*, 4th month (July) 5th month (August) and 6th month (September) for *C. cirrhosus* and 4th month (July) for *B. gonionotus*.

The lowest combined SGR value was found as 0.30±0.03 (T_2 at 6th month) and the highest combined SGR was found as 2.62±0.17 (T_0 at 1st month). The highest SGR value was found in the month of April and the lowest value was found in the month of September for all the species. The lowest SGR value in the month of September might be due to the slow growth rate at mature stage of fishes. Slow growth due to slow metabolic activity of fish is found in lower water temperature (Boyd, 1998).

Monthly weight gain (g/month)

The weight gain (g/month) varied with *H. molitrix* from 28.67±0.67 g (T_3 at 6th month) to 109.67±2.03 g (T_0 at 4th month), *C. catla* from 28.33±1.20g (T_3 at 6th month) to 154.33±3.84 g (T_0 at 4th month), *L. rohita* from 19.33±1.45 g (T_2 at 6th month) to 90.67±1.20 g (T_0 at 3rd month), *C. cirrhosus* from 22.67±3.33 g (T_3 at 6th month) to 90.00±0.58 g (T_0 at 3rd month), *C. carpio* from 29.67±0.33 (T_3 at 6th month) to 96.00±1.53 g (T_0 at 4th month), *C. idella* from 53.33±0.88 (T_2 at 6th month) to 111.33±4.37 g (T_1 at 3rd month) and *B. gonionotus* from 4.67±0.33 (T_2 at 6th month) to 50.00±0.58 g (T_1 at 3rd month). Among the different species, the highest monthly weight gain observed in *C. catla* as 154.33±3.84 g (T_0 at 4th month) might be due to higher nutrient concentration resulting from regular supply of feed and fertilizer. Jena *et al*. (2002b) mentioned that *C. catla* showed a better growth performance than other carp species. Lowest value in *B. gonionotus* as 4.67±0.33 g (T_2 at 6th month) was due to slow growth pattern of this species. Significant variation was found in all months for all the species except the 2nd month (May) and 3rd month (June) for *C. idella*. The lowest combined weight gain value was found as 29.10±5.66 (T_2 at 6th month) and the highest combined weight gain was found as 94.52±13.75 (T_0 at 4th month). The highest weight gain was found in the month of July and the lowest value was found in the month of September for all the species. It might be due to higher metabolic rate at comparatively higher temperature. Comparatively higher mean monthly weight gain was observed at the middle period of the experiment, this might be due to influence of air temperature on water temperature resulting fast metabolic activity (Boyd, 1998).

Mean variations

Specific Growth Rate (%, bwd^{-1})

The mean specific growth rate (SGR, %, bwd^{-1}) varied with *H. molitrix* from 0.94±0.21 (T_3) to 1.29±0.41 (T_0), *C. catla* from 0.96±0.24 g (T_3) to 1.31±0.24 (T_0), *L. rohita* from 0.84±0.16 (T_3) to 1.21±0.38 (T_0), *C. cirrhosus* from 0.87±0.15 (T_3) to 1.24±0.38 (T_0), *C. carpio* from 0.93±0.22 (T_3) to 1.20±0.34

(T_0), *C. idella* from 1.03±0.23 (T_0) to 1.31±0.31 (T_1) and *B. gonionotus* from 0.85±0.21 (T_3) to 1.05±0.25 (T_1). Jasmine, *et al.* (2011) found the mean SGR of silver as 1.26 to 1.40 %, bwd^{-1} and catla as 1.19 to 1.21 %, bwd^{-1} in polyculture pond. The mean SGR (%, bwd^{-1}) of catla, rohu and mrigal in different treatments under polyculture system were recorded as 1.09 to 1.12, 1.13 to 1.14 and 1.10 to 1.12 (Rahman *et al.* 2007). Kohinoor *et al.* (1999) observed the SGR value of Thai sharpunti to be between 1.33 and 1.35 %, bwd^{-1} in polyculture with carps using low-cost feed. However, among the species comparively highest SGR (1.31 ± 0.31% bwd^{-1}) was obtained for *C. idella* in treatment T_1, where Azolla was supplied as feed and the lowest SGR (0.84 ± 0.16) for *L. rohita* in treatment T_3 where banana leaf was supplied. It is clear that grass carp grows well with Azolla fed pond. Majhi *et al*. (2006) recorded SGR value of *C. idella* as 1.65 %, bwd^{-1} in Azolla fed fish pond. The lowest SGR value found as 0.93±0.03 (T_3) might be due to intake of banana leaf only by the macrophytophagus species and the highest combined SGR as 1.17±0.05 (T_0) might be due to combined effect of conventional feed and natural feed. Ferdoushi *et al*. (2008) reported that supply of Azolla with conventional feed showed better growth performance than that of only used conventional feed in carp polyculture system.

Weight gain (g/month)

Mean weight gain (g/month) significantly varied with *H. molitrix* from 45.72±4.66 g (T_3) to 95.78±5.56g (T_0), *C. catla* from 49.06±5.28 g (T_3) to 102.45±14.41g (T_0), *L. rohita* from 33.39±3.30 g (T_2) to 74.17±6.55g (T_0), *C. cirrhosus* from 33.78±3.68 g (T_3) to 74.33±5.59 g (T_0), *C. carpio* from 46.00±4.51 g (T_3) to 80.61±4.99 g (T_0), *C. idella* from 72.84±5.13 g (T_3) to 95.17±6.99 g (T_1) and *B. gonionotus* from 15.11±1.95 g (T_3) to 34.95±4.53 g (T_1). Azad *et al*. (2004) reported the weight gain of *H. molitrix* as 72.87 g and *C. cirrhosus* as 70.42 g while working with carp polyculture using low cost inputs. Among the species the highest weight gain was observed as 102.45±14.41 g in *C. catla,* which might be due to stocking of comparatively larger sized fingerlings. The lowest weight gain was found in *B. gonionotus* as 15.11±1.95 g which might be due to slow growth rate. Azim *et al*. (2004) worked on feeding relation in a carp polyculture system and they found that weight of *C. catla* was moderate and weight gain *B. gonionotus* was lowest. The lowest combined mean weight gain was found as 42.33±6.71 g (T_3) and the highest combined weight gain as 76.64±9.24 g (T_0) for all the species. The lowest combined weight gain (T_3) might be due to apply only non-conventional feed (banana leaf) which is consumed only by the macrophytophagous species. On the other hand, highest combined weight gain (T_0) might be due to the use of conventional feed and naturally produced feed, which is favourable for better growth of all species.

Final Weight (g)

The mean final weight (g) varied with *H. molitrix* from 336.33±2.03 (T_3) to 636.67±5.61 g (T_0), *C. catla* from 358.33±4.41 (T_3) to 678.67±12.57 g (T_0), *L. rohita* from 257.33±5.04 (T_2) to 502.00±2.08 g (T_0), *C. cirrhosus* from 256.67±1.76 (T_3) to 500.00±7.23 g (T_0), *C. carpio* from 339.00±3.79 (T_3) to 546.67±8.69 g (T_0), *C. idella* from 502.00±4.16 (T_3) to 620.33±18.02 g (T_1) and *B. gonionotus* from 115.67±2.60 (T_3) to 229.67±2.67 g (T_1). Rahman *et al.* (2006) reported the final weight of rui, catla, mrigal, silver carp and thai sharputi as 144.71g, 189.44g, 89.68g, 302.70g and 79.21g respectively in polyculture system over 90 days of rearing. The growth rate of *C. carpio* recorded by Das (2000) was 170.0 g and was 97.78 g by Azad *et al*. (2004) which were less than the final weight obtained in the present study. It might be due to the good water quality, regular supply of feed and Azolla, larger stocking size of fingerlings. Majhi, *et al.* (2006) reported the final weight of 270.34g in *C. idella* fed with Azolla in 150 days culture period at a stocking density of 0.75 fish/m^2 and initial stocking size of 23.50 ± 5.0g. Among the species the highest final weight was observed as 678.67±12.57 g in *C. catla* and the lowest was in *B. gonionotus* as 115.67±2.60 g. The lowest mean final weight was found as 2167.67±17.31 g (T_3) and the highest final weight as 3629.34±19.52 g (T_0) for all the species. The reason behind the highest final weight might be due to proper utilization of both natural and supplementary feed.

Survival rate (%)

The survival rate (%) varied with *H. molitrix* from 81.33±1.20 (T_2) to 84.33±2.03% (T_0), *C. catla* from 75.33±1.59 (T_2) to 81.00±1.73% (T_0), *L. rohita* from 77.67±1.45 (T_3) to 81.33±0.88% (T_0), *C. cirrhosus* from 67.50±1.44 (T_2) to 80.33±2.91% (T_0), *C. carpio* from 78.00±1.73% (T_2) to 86.33±2.40% (T_0), *C. idella* from 73.00±1.15 (T_0) to 83.00±1.15% (T_1) and *B. gonionotus* from 70.33±1.45 (T_0) to 78.67±0.67% (T_1). Das *et al*. (1982) reported that the survival of rohu, catla, mrigal and silver carp were 88.64 - 90.18, 85.81 - 90.06, 84.93 - 91.36 and 92.35 - 96.96%, respectively in polyculture of indigenous and exotic fish species. Roy *et al*. (2002) reported the survival rate of grass carp, rohu, catla and mrigal as 76.6%, 87.8%, 84.0% and 88.6%, respectively in carp polyculture with SIS. Mostaque (1995) recorded the survival rates as 86% to 95% in a polyculture system in ponds. Khan *et al*. (2009) also recorded 83.2% survival rate for silver carp while working in carp polyculture system.

Among the species the highest survival rate was observed as 86.33±2.40% in *C. carpio* and the lowest in *C. cirrhosus* as 67.50±1.44%. This might be due to high tolerance capability of *C. carpio* than other carp species. Azad *et al*. (2004) found the lowest survival rate for *C. cirrhosus* among carp species.

The lowest combined mean survival rate was found as 76.33±1.74% g (T_2) and the highest survival rate as 79.52±2.20% (T_0) for all the species which might be due to available supply of food for all species. Wahab *et al*. (1995) reported that the combined survival rate was 80% in polyculture system.

Yield (Kg/ha/6 months)

The yield (Kg/ha/6 months) varied with *H. molitrix* from 636.00±3.79 (T_3) to 1250.00±14.43 (T_0), *C. catla* from 186.67±2.03 (T_3) to 426.33±8.41 (T_0), *L. rohita* from 479.33±924 (T_2) to 992.00±4.16 (T_0), *C. cirrhosus* from 269.67±1.76 (T_3) to 555.00±7.81 (T_0), *C. carpio* from 226.00±2.65 (T_3) to 385.00±6.03 (T_0), *C. idella* from 527.00±4.16 (T_3) to 603.67±71.64 (T_1) and *B. gonionotus* from 214.33±4.63 (T_3) to 375.67±41.34 (T_1). Majhi *et al*. (2006) worked on effect of Azolla feeding on growth performance of grass carp and obtained total production of grass carp (*C. idella*) was 185.76 kg/1000m^2 in 150 days culture period. Roy *et al*. (2002) recorded the yield of catla as 698.4, followed by

L. rohita as 754.1, *C. cirrhosus* as 761.4 and *C. idella* as 346.5 kg/ha/7 months at a stocking density of 3167, 3167, 3166 and 500 individual/ha, respectively supplied with only rice brain.

Among the species the highest yield was observed as 1250.00±14.43 kg/ha/6 months in *H. molitrix* and the lowest was in *C. catla* as 186.67±2.03 kg/ha/6 months. This might be the result of higher stocking density of *H. molitrix* and competition for food with *C. catla*. A severe competition for food between planktivorous native carps and exotic carps has been observed by Dewan *et al.* (1991). The maximum total fish production as 4403.51 kg was obtained in T_0, where conventional feeds were supplied and lower production as 2541.00 kg/ha/6 months in T_3, where only banana leaf was supplied as feed. Moderate production was obtained in T_1 (Azolla fed) and comparatively lower production was obtained in T_2 (grass fed). However, significant difference in total fish production was found among the treatments. It is clear that use of conventional feed, Azolla, grass and banana leaf has direct effect on the total production in polyculture system.

Uddin *et al.* (1994) found a gross production of 3,415 kg/ha/yr from polyculture of carps with rajpunti. Islam *et al.* (1997) obtained a net yield of 2,966 kg/ha/7 months by culturing silver carp, common carp and tilapia in seasonal ponds through fertilization and supplementary feeding. Mahmud (1998) reported a total gross production of 1,713.4 kg/ha/120 days in a four species composite culture of major carps including Thai sharpunti through the application of fertilizer and supplementary feed comprising of rice bran (60%) and mustard oil cake (40%) daily at the rate of 3% of fish biomass and duckweed (*Lemna minor*) at the rate of 10% of the body weight of thai sharpunti. Miaje (1999) reported the total production of fish from 2,934 to 3,318 kg/ha/4 months in polyculture of Indian major carps with Thai sharpunti fed supplementary diet containing 20.31% crude protein. Das *et al*. (1982) reported a total gross production of 2,102.50-4,361.43 kg/ha/year on polyculture of major carps with the application of fertilizer and supplementary feed consisting of rice bran (75%) and mustard oil cake (25%). The total productions of fish obtained from the present study are similar to those reported by Das *et al.* (1982) and Mahmud (1998), higher than those of Uddin *et al.* (1994), Islam *et al.* (1997) and nearly closer to Miaje (1999). Roy *et al*. (2003) obtained total yield as 2560 kg/ha/7 months in carp polyculture system which was found lower as compared to the present study. Azim and Wahab (2003) also recorded total yield as 2020 kg/ha/4 months in duckweed based system.

4.4.3: Economics

Economic viability is an important criterion for sustainability of any system. Economic analysis provides a basis not only for the decision making of the individual fish farmer, but also for the formulation of aquaculture policies (Shang, 1981). During study period total cost, gross benefit, net benefit and CBR varied from 123430.50±0.00 BDT/ha/6 months (T_1, T_2, T_3) to 235930.50±0.00 BDT/ha/6 months (T_0), 235068.40±1965.31 (T_3) to 418376.85±5125.59 BDT/ha/6 months (T_0), 111639.90±2056.87 (T_3) to 206744.85±3221.73 BDT/ha/6 months (T_1) and 0.77±0.02 (T_0) to 1.67±0.18 (T_1), respectively.

Total cost was higher in Treatment T_0 which might be due to the feed cost (47.68% of total cost). Abdelghany and Ahmad (2002) worked on cost-benefit analysis in polyculture system and they reported total cost was BDT/ha 2,15,202.00 which was closer to the present study.

Gross benefit in Treatment T_1 was 330175.35±2155.32 BDT/ha which was more or less similar to the findings of Abdelghany and Ahmad (2002) who worked on cost-benefit analysis in carp polyculture pond reported gross benefit from fish sale was BDT/ha 309524.3.0.

In case of net benefit, Grover *et al*. (2000) described the net benefit of the Azolla based carp polyculture in ponds was 310990 Tk/ha/year. Shamugasundaram and Balusamy (1993) stated benefit cost ratio as 1.88 which was similar to the present study. Khan *et al*. (2009) also mentioned BCR value of 1.22 which was lower than the findings of the present study, this might be due to high initial biomass of all the species and the higher survival rate of fishes in the present study.

Data on economics indicated that the treatment T_1 (Azolla fed pond) was more profitable than that of others.

Overall findings indicated that in treatment T_1 (Azolla fed pond), the water quality parameters were found in suitable range for fish growth, fish production was moderately high and cost benefit ratio was found highest. Azolla, which grows in association with the blue green algae *Anabaena azollae*, is perhaps the most promising from the point of view of ease of cultivation productivity and nutritive value (Lumpkin and Plucknett 1982; Van-Hove and Lopez 1983). Azolla-fed fish pond provides with a complete and balanced diet for those fish that consume it directly, while the faces of Azolla feeding species are consumed directly by detritus feeders, or indirectly used as fertilizer, enhancing plankton and other food organisms, which can be utilized by remaining surface and column feeding fish species . Providing Azolla as supplementary feed in this system could minimize the food competition between native carps and macrophytes (Journey *et al*., 1990). Therefore, the present finding regarding the potentials of aquaculture with non-conventional feed specially with Azolla as a low cost farming are proven and agreed well by the aforementioned scientists.

4.5: Conclusion

Considering the water quality, fish production and economic viability it can be concluded that Azolla based carp polyculture is more profitable as well as low cost culture technology and potentially be used for poor fish farmer.

4.6: Recommendation

This study identified Azolla based fish farming as a potential low cost aquaculture. On the other hand the major limitation of this study was with using only one stocking density for all treatments. Therefore, possibilities of finding maximum fish production under Azolla based fish farming was not explored in terms of suitable stocking density. So, it is recommended that optimization of stocking density for Azolla based carp polyculture in ponds should be explored as further research step.

CHAPTER FIVE

Optimization of stocking density for Azolla based carp polyculture in pond

5.1: Introduction

Polyculture or composite culture is the system in which fast growing compatible species of different feeding habits are stocked in different proportions in the same ponds (Jhingran, 1975). The basic principles of the polyculture, species of different feeding habits are culture in the same pond to avoid food competition and best utilization of natural foods of different habits without any harm to each other. It is a fact that, polyculture may produce an expected result if the fish with different feeding habits are stocked in proper ratios and combinations (Halver, 1984). Selection of species plays an important role for any cultural practices. For better utilization of different strata and zones of a pond three or more species must be stocked. In our country, suitable or common combinations of fish for composite culture are rui (*Labeo rohita*), catla (*Catla catla*) and mrigal (*Cirrhinus cirrhosus*) (Miah *et al*., 1997).

In order to obtain more production several exotic carps cultured combined with the local carps. These include silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*), common carp (*Cyprinus carpio*), raj punti (*Barbonymus gonionotus*) etc. In search of compatible fish species for polyculture, Wahab *et al*. (2002) observed that common carp (*Cyprinus carpio*) grew better than its counter-part native species mrigal and did not exert significant antagonistic impact on other native carp species in polyculture. Thai silver barb (*Barbodes gonionotus*) has become increasingly popular owing its bright silvery appearance and good taste. This fish is an omnivorous and reportedly grows well on macrophytes (Phaohorm, 1980; Rothuis *et al*., 1998). It has been proven to be a suitable species for culturing in the seasonal ponds (Islam *et al*., 1998; Kohinoor *et al*., 1999) and rice fields (Haroon and Pittman, 1997; Vromant *et al*., 2002).

Freshwater fishes dominate global aquaculture production (56.4%, 33.7 million tonnes), followed by molluscs (23.6%, 14.2 million tonnes), crustaceans (9.6%, 5.7 million tonnes), diadromous fishes (6.0%, 3.6 million tonnes), marine fishes (3.1%, 1.8 million tonnes) and other aquatic animals (1.4%, 814 300 tonnes). While feed is generally perceived to be a major constraint to aquaculture development, one-third of all farmed food fish production (20 million tonnes) is currently achieved without artificial feeding, as is the case for bivalves and filter-feeding carps. However, the percentage of non-fed species in world production has declined gradually from more than 50 percent in 1980 to the present level of 33.3 percent, reflecting the relatively faster body-growth rates achieved in the culture of fed species and increasing consumer demand for higher trophic-level species of fishes and crustaceans (FAO, 2012).

According to FAO (2008) estimates, about 31.7 million tonnes (46.1% of total global aquaculture production including aquatic plants) of fish and crustaceans are feed-dependent, either as farm-made aqua feeds or as industrially manufactured compound aquafeeds. In 2008, fed aquaculture contributed to 81.2% of global farmed fish and crustacean production of 38.8 million tonnes and 60.0 percent of global farmed aquatic animal production.

While more than 200 species of fish and crustaceans are currently believed to be fed on externally supplied feeds, just 8 species or species groups account for 62.2% of the total feed used. These are: grass carp, common carp, Nile tilapia, Indian major carps (catla and rohu), white leg shrimp, crucian carp, Atlantic salmon, and pangasiid catfishes. More than 67.7% of farmed fish production is contributed by freshwater fishes, including carps and other cyprinids, tilapias, catfishes and miscellaneous freshwater fishes (FAO, 2012).

Farm-made aqua feeds play an important role in the production of low-value freshwater fish species. More than 97% of carp feeds used by Indian farmers are farm-made aqua feeds (7.5 million tonnes in 2006/07), and they are the mainstay of feed inputs for low-value freshwater fishes in many other Asian and sub-Saharan countries (FAO, 2012).The main production systems for freshwater aquaculture in Bangladesh are extensive and semi-intensive pond polyculture of Indian and Chinese major carps which account for 80% of the total freshwater production. The remaining 20% are mainly from catfish, tilapia, small indigenous species (SIS) of fish and rice fish farming (ADB, 2005).

The traditional model of carp polyculture is conceptually elegant, and a great deal is known about the nutritional value of supplementary inputs. However, to achieve the highest productivity from a carp pond still involves a high degree of art. High production with current techniques requires a delicate and precarious balancing act between fish density, feed, fertilizer inputs, potential competitors and the amount of dissolved oxygen in the pond (FAO, 2008).

Stocking density is an important parameter in fish culture operations, since it has direct effects on the growth and survival and hence on production (Backiel and Le Cren, 1978). It is an established fact that the growth rate progressively increases as the stocking density decreases and vice-versa. This is because of relatively less number of fish in a pond of similar size could get more space food and dissolved oxygen at the same time. The growth of fishes is dependent on population density (LeCren, 1965; Backiel and LeCren, 1978), Generally direct relationship exists between food abundance and growth rate as well as between population density of the species and its growth rate, where as population density of the species and its growth rate tend to be inversely related (LeCren, 1965). However, there may be no relationship between food abundance and growth rate, when a space limiting effect operates on the population. Higher stocking density may cause crowding effects and reduction of growth rate. Size hierarchies within the fish population as a result, smaller fish 'is inhibited from feeding satisfactorily because of the presence of the larger ones. In many fish culture practices where the fish are confined in a restricted space, this size dominance in feeding is often of considerable significance (Brett, 1979).

One of the major problems faced by rapidly growing aquaculture is the availability of fish feed, since feed is the largest operating cost of semi-intensive fish farming. Feeding cost often constitutes more than 50% of the total cost of production in intensified culture system (Sehagal and Toor, 1991 and De Silva, 1992).The common supplementary feeds in Bangladesh are rice bran, wheat bran, oil cake and some other agricultural wastes. As a resource constrained country, there is a severe competition for these agricultural wastes especially between raising livestock and fuel. Besides, the increase in cost and demand of feed protein from these conventional resources necessitates fish culturists of the developing countries to incorporate cheap and locally available ingredients in fish feeds. Therefore, the aqua farmers have been exploring the possibilities of utilizing alternative sources having high food value like plant leaves and aquatic vascular plants for producing the much required animal protein at low cost (Lakshmanan *et al*., 1967). Azolla, which grows in association with the blue green algae *Anabaena azollae*, is perhaps the most promising from the point of view of ease of cultivation, productivity and nutritive value (Lumpkin and Plucknett, 1982; Van-Hove and Lopez, 1983). Fish require diets relatively higher in protein than those of commercially cultured animals. As protein represents the most expensive component in a formulated diet, it is of considerable practical importance to determine the optimum level that will support maximum growth and survival. Azolla contains 20- 25.5% protein, 3.1% fat, 34.9% carbohydrate, 8.5-11.7% cellulose and essential aminoacids. Biochemical and physiological changes in organisms influence the activities of some enzymes and metabolic levels of some tissues (Murty, 1986). It appears to be suitable for a wide range of fish species and may also be applied in the polyculture systems. It can be fed fresh as a sole feed or as an ingredient in combination with other components in artificial feed. A Azolla-fed fish pond provides with a complete and balanced diet for those fish that consume it directly, while the faeces of Azolla feeding species are consumed directly by detritus feeders, or indirectly used as fertilizer, enhancing plankton and other food organisms, which can be utilized by remaining surface and column feeding fish species . Providing Azolla as supplementary feed in this system could minimize the food competition between native carps and macrophytes (Journey *et al*., 1990).

It would be one of the cheapest ways in organic fish farming to increase the fish production from the aquatic habitat. This would also pave way for producing organic fish and narrow the wide gap between the production and demand of organic fish in the country. Above all, organic fish production would also increase, the farm income and living standard of low income farmers of the region.

Quantitative data on this issue are thus still very scarce to make reliable predictions of optimization of stocking density for Azolla based carp polyculture in pond. So far little or no experimental evidence exists for optimization of stocking density for Azolla based carp polyculture in pond polyculture system in Bangladesh or elsewhere in the region. Therefore, the present study aimed at evaluating the production and economics of Azolla based carp polyculture under different treatments of stocking densities.

5.2: Specific objectives

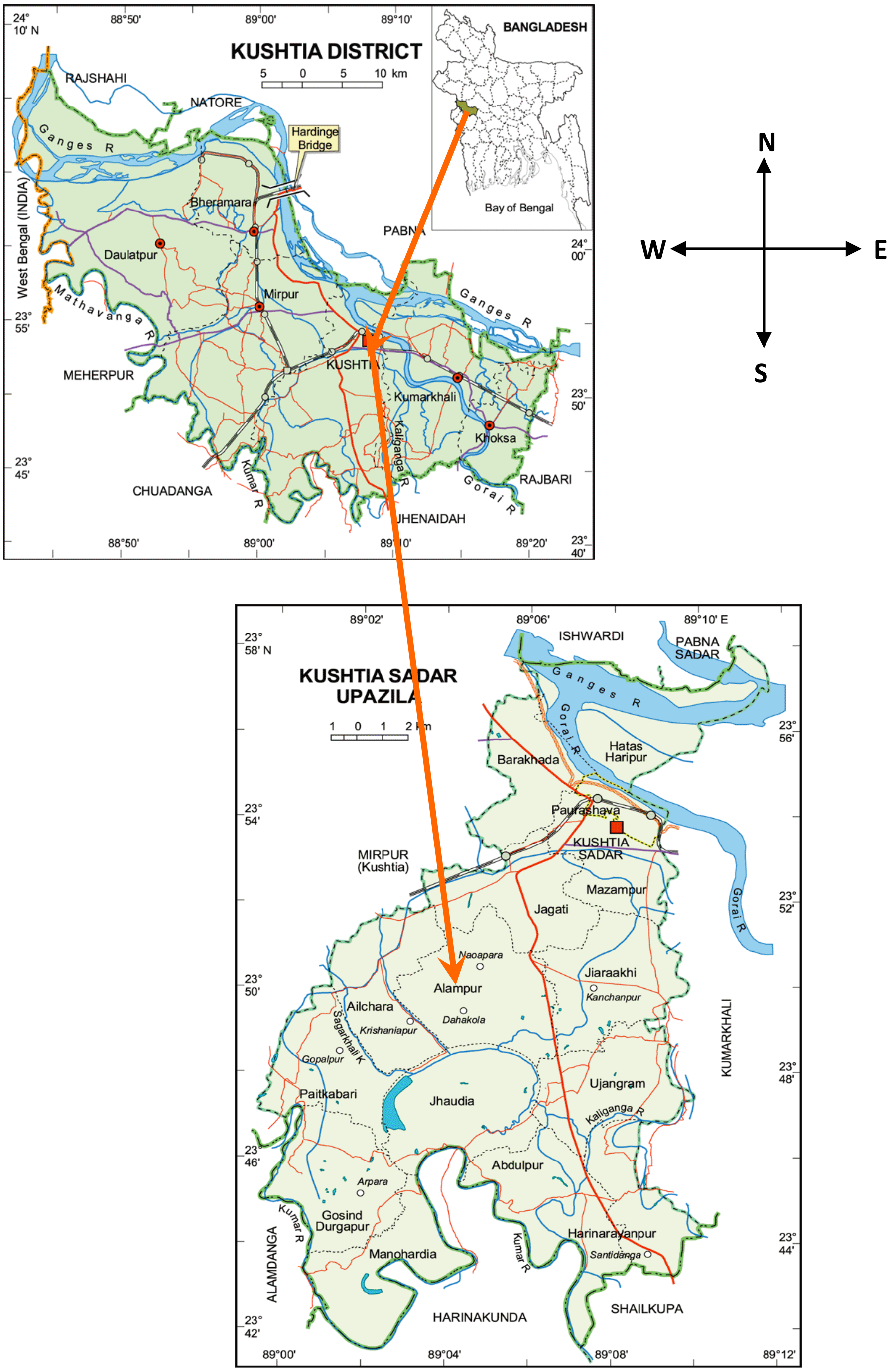
The specific objectives of this study were as follows-

- to monitor the water quality parameters (in terms of temperature, transparency, dissolved oxygen, pH, alkalinity and CO_2) in Azolla fed carp polyculture ponds under different treatments of stocking densities;
- to evaluate the growth performance of fishes under different treatments of stocking densities;
- to evaluate the economics of fish production under different treatments of stocking densities; and
- finally, to recommend suitable stocking density for Azolla based carp polyculture in ponds.

5.3: Materials and methods

5.3.1: Duration and location of the study

The study was conducted for a period of six months from April 2012 to September 2012 at Alampur village of Sadar Upazila under Kushtia district, Bangladesh (Map 5.1).



Map 5.1 : Shows the study area.

5.3.2: Description of the study ponds

A total of 9 ponds (average water area of 0.18ha and depth of 1.9 m) were selected for the present study. All the ponds were rain-fed and well exposed to sunlight (Plate 5.1).

5.3.3: Experimental design

The experiment was designed under Randomized Completely Block Design (RCBD) with three treatments (T_1, T_2 and T_3) of carp stocking densities each with three replications. The treatment assignment was as follows-

T_1 : 40 fish/decimal (9880 fish/ha)
T_2 : 45 fish/decimal (11115 fish/ha)
T_3 : 50 fish/decimal (12350 fish/ha)

Stocking ratio/combination of fish species were same for all the treatments (Table 5.1).

5.3.4: Pond management

Aquatic weeds were removed from all the ponds manually. Predatory fish and other unwanted species were removed through repeated netting. All the ponds were facilitated well with Azolla bank.

Liming was done at a rate of 250 kg/ha before 7 days of fertilization. All the ponds were fertilized with cowdung (1500 kg/ha), urea (60 kg/ha) and Triple Super Phosphate (TSP) (60 kg/ha) as basal dose.

One tenth area of the research ponds were used as Azolla bank according to Grover *et al*. (2000). Azolla bank was prepared by bamboo fencing (locally called ‘Bana’). In Azolla bank, compost manure was deposited (2470 kg/ha). Azolla seeds were introduced in Azolla bank at the rate of 1000 kg/ha for available supply of Azolla at the culture period.

Fishes were stocked in all ponds after five days of basal fertilization. All the ponds were stocked with seven species of fishes (mean initial weight of *Hypophthalmichthyes molitrix*, *Catla catla*, *Labeo rohita*, *Cirrhinus cirrhosus*, *Cyprinus carpio*, *Ctenopharyngodon idella* and *Barbonymus gonionotus* were 60, 65, 58, 52, 61, 70 and 22 g, respectively).

Fish seeds were collected from local government fish farm. Stocking of fish seeds were done at early morning. Stocking density and stocking ratio/combination are shown in Table 5.1 (Grover *et. al*., 2000).

Table 5.1: Stocking density and stocking ratio/combination of fish species.

	Treatments→	**T_1**		**T_2**		**T_3**	
Pond layer	**Fish species**	**No. of species/ dec**	**No. of species/ ha**	**No. of species/ dec**	**No. of species / ha**	**No. of specie s/ dec**	**No. of species/h a**
Surface layer	1. *H. molitrix* 2. *C. catla*	8 2	1976 494	9 3	2223 741	10 4	2470 988
Middle layer	3. *L. rohita*	9	2223	10	2470	11	2717
Bottom layer	4. *C. cirrhosus* 5. *C. carpio*	4 2	988 494	5 3	1235 741	6 4	1482 988
All layer	6. *C. idella* 7. *B. gonionotus*	5 10	1235 2470	5 10	1235 2470	5 10	1235 2470
	Total	**40**	**9880**	**45**	**11115**	**50**	**12350**

After stocking, TSP was applied (2.5 kg/ha/day) for ponds under all treatments as periodic fertilization.

In ponds under all treatments, Azolla (100%) was supplied as supplementary feed daily at the rate of 100% of the body weight of herbivorous fishes (*C. idella* and *B. gonionotus*). Azolla was supplied from Azolla bank and made available 24 hours per day (Plate 5.2).

5.3.5: Water quality monitoring

Some important physico-chemical parameters of water such as water temperature, transparency, dissolved oxygen (DO), pH, alkalinity and carbon-dioxide (CO_2) were monitored fortnightly between 10:00 AM to 11:00 AM for the present study (Plate 5.3).

5.3.5.1: Water temperature

During the study period, water temperature was recorded with the help of a celsius thermometer at 20-30 cm depth of water. The data were expressed as °C.

5.3.5.2: Water transparency

Measurement of limit of visibility i.e. penetration of light in water was done by a Secchi disc. The data thus obtained, were expressed as secchi disc depth in centimeter.

5.3.5.3: Dissolved oxygen (DO)

The dissolved oxygen concentration of water was determined by the aid of a water quality test kit (HACH kit FF-2, USA). Alkaline iodide-azide powder pillows, manganese sulfate powder pillows, sodium thiosulfate titration cartridge (0.2000 N), starch indicator solution and sulfamic acid powder pillows were used for determination of dissolved oxygen. The concentration of dissolved oxygen thus estimated was expressed in milligram per litter (mg/l) of water.

5.3.5.4: Hydrogen ion concentration (pH)

pH was measured by using HACH kit (FF-2, USA). Wide range 4 pH indicator solution (1919-00) were used for determination of water pH. A colour comparator disc ranging from 1-14 was also used for this purpose.

5.3.5.5: Alkalinity

Alkalinity was determined through digital titration by the help of a HACH kit (FF-2, USA). Bromcresol green-methyl red powder pillows, phenolphthalein powder pillows and sulfuric acid titration cartridge (0.1600 N) were used for total alkalinity determination. It was also expressed as mg/l of water.

5.3.5.6: Free carbon dioxide (CO_2)

Free carbon dioxide was determined through digital titration by the help of a HACH kit (FF-2, USA). Phenolphthalein powder pillows and sodium hydroxide titration cartridge (0.3636 N) were used for determination of carbon dioxide. It was also expressed as mg/l of water.

5.3.6: Growth monitoring of fishes

At least 10% (by number) of the fish in each pond were randomly sampled on a monthly basis with a cast net. On each sampling day, individual fish from each pond were weighed and measured. The purpose was to determine fish growth in weight and to adjust the ration. Following growth parameters were used for the present study (Plate 5.4).

Weight gain (g) = Mean final weight (g) - Mean initial weight (g)

Final weight (g) = Weight of fish at harvest (g)

Specific Growth Rate, SGR (% bwd^{-1}) = [L_n (final weight) – L_n (initial weight)] / culture period (days) $\times$ 100

(Brown, 1957)

Survival rate (%) = $\frac{\text{Number of fish harvested}}{\text{Number of fish stocked}} \times 100$

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

5.3.7: Economics

Simple economical analysis of the different treatments was performed during the study period. On the basis of the fixed and variable expenditure, the total cost (BDT/ha) was estimated. At the end of the experiment, fishes were sold locally and the gross benefit (BDT/ha) was estimated. Net benefit (BDT/ha) was estimated by deducting the total cost from gross benefit. The following parameters were used to explore the economics of different treatments:

Net profit margin (%) = $\frac{\text{Net benefit}}{\text{Total investment}} \times 100$

CBR (Cost-Benefit Ratio) = $\frac{\text{Net benefit}}{\text{Total investment}}$

5.3.8: Statistical analysis

Data on water quality parameters, fish production and economics under different treatments were subjected to one way ANOVA (Analysis of Variance) using computer software SPSS (Statistical Package for Social Science, version-11). The mean values were also compared to see the significant difference from the DMRT (Duncan Multiple Range Test) after Gomez and Gomez (1984).

Plate 5.1: Experimental ponds

Plate 5.2: Supply of Azolla in experimental pond.

Plate 5.3: Monitoring of water quality parameters

Plate 5.4: Measurement of growth of fishes.

5.4: Results

5.4.1: Water quality

5.4.1.1: Fortnightly variations

The variations in the mean values of water quality parameters in different treatments at different fortnights are presented in table 5.2 to table 5.13.

Water temperature

During the study period, water temperature varied from 30.13±0.15 to 33.47±0.18°C. The minimum value was recorded in treatment T_3 at 12th fortnight whereas the maximum value was recorded in treatment T_3 at 6th fortnight.

Water transparency

Water transparency value was found to range from 30.33±0.88 to 34.67±0.33 cm. The minimum value was recorded in treatment T_3 at 8th fortnight whereas the maximum value was recorded in treatment T_1 at 2nd and 4th fortnight.

Dissolved Oxygen (DO)

Dissolved oxygen of water varied from 5.00±0.06 to 6.15±0.10 mg/l. The minimum value was recorded in treatment T_3 at 7th and 8th fortnight whereas the maximum value was recorded in treatment T_1 at 4th fortnight.

Hydrogen ion concentration (pH)

pH value of water varied from 6.93±0.07 to 8.10±0.06. The minimum value was recorded in treatment T_3 at 7th fortnight whereas the maximum value was recorded in treatment T_3 at 3rd fortnight.

Alkalinity

Alkalinity of water was found to range from 106.33±1.76 to 123.00±1.53 mg/l. The minimum value was recorded in treatment T_2 at 1oth fortnight whereas the maximum value was recorded in treatment T_3 at 3rd fortnight.

Free carbon dioxide (CO_2)

Free CO_2 value was found to range from 2.03±0.03 to 3.18±0.07 mg/l. The minimum value was recorded in treatment T_1 at 6th fortnight whereas the maximum value was recorded in treatment T_3 at 12th fortnight.

Among the water quality parameters the values of transparency (at 2nd, 7th and 11th fortnight), DO (at 1st, 2nd, 3rd, 5th and 6th fortnight), pH (at 3rd fortnight), alkalinity (at 3rd, 4th, 7th, 9th and 10th fortnight) and CO_2 (at 3rd, 4th, 8th and 10th fortnight) differed significantly among the treatments.

Table-5.2: Variations in the mean values of water quality parameters under different treatments at 1st fortnight

Parameters \ Treatments	T_1	T_2	T_3
Water temperature (°C)	32.47±0.20[a]	32.30±0.17[a]	32.30±0.10[a]
Transparency (cm)	32.33±1.45[a]	31.33±0.88[a]	32.33±0.88[a]
DO (mg/l)	5.63±0.07[a]	5.13±0.09[b]	5.20±0.06[b]
pH	7.57±0.15[a]	7.48±0.07[a]	7.52±0.09[a]
Alkalinity (mg/l)	109.33±0.33[a]	113.00±3.61[a]	116.00±2.31[a]
Free CO_2 (mg/l)	2.73±0.05[a]	3.05±0.03[a]	2.96±0.01[a]

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-5.3: Variations in the mean values of water quality parameters under different treatments at 2nd fortnight

Parameters \ Treatments	T_1	T_2	T_3
Water temperature (°C)	32.30±0.12[a]	32.47±0.20[a]	32.10±0.15[a]
Transparency (cm)	34.67±0.33[a]	32.00±0.58[b]	33.67±0.33[a]
DO (mg/l)	5.80±0.06[a]	5.27±0.12[b]	5.17±0.15[b]
pH	7.43±0.09[a]	7.20±0.12[a]	7.43±0.09[a]
Alkalinity (mg/l)	115.00±1.53[a]	116.00±4.04[a]	109.67±0.88[a]
Free CO_2 (mg/l)	2.88±0.04[a]	2.95±0.05[a]	3.01±0.05[a]

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-5.4: Variations in the mean values of water quality parameters under different treatments at 3rd fortnight

Parameters \ Treatments	T_1	T_2	T_3
Water temperature (°C)	31.43 ± 0.23^{a}	31.30 ± 0.06^{a}	31.30 ± 0.06^{a}
Transparency (cm)	33.00 ± 0.58^{a}	33.67 ± 0.88^{a}	33.33 ± 0.88^{a}
DO (mg/l)	5.93 ± 0.09^{a}	5.40 ± 0.25^{ab}	5.37 ± 0.03^{b}
pH	7.83 ± 0.09^{ab}	7.70 ± 0.10^{b}	8.10 ± 0.06^{a}
Alkalinity (mg/l)	115.33 ± 4.26^{ab}	123.00 ± 1.53^{a}	110.00 ± 1.15^{b}
Free CO_2 (mg/l)	2.65 ± 0.07^{b}	3.01 ± 0.04^{a}	3.05 ± 0.10^{a}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-5.5: Variations in the mean values of water quality parameters under different treatments at 4th fortnight

Parameters \ Treatments	T_1	T_2	T_3
Water temperature (°C)	31.17 ± 0.03^{a}	31.23 ± 0.09^{a}	31.43 ± 0.09^{a}
Transparency (cm)	34.67 ± 0.33^{a}	32.00 ± 1.15^{a}	32.33 ± 0.67^{a}
DO (mg/l)	6.15 ± 0.10^{a}	5.98 ± 0.06^{a}	5.82 ± 0.08^{a}
pH	7.83 ± 0.12^{a}	7.73 ± 0.19^{a}	7.63 ± 0.19^{a}
Alkalinity (mg/l)	118.00 ± 1.73^{a}	108.67 ± 1.76^{b}	112.33 ± 3.53^{ab}
Free CO_2 (mg/l)	2.81 ± 0.05^{b}	2.95 ± 0.07^{ab}	3.03 ± 0.03^{a}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-5.6: Variations in the mean values of water quality parameters under different treatments at 5th fortnight

Parameters \ Treatments	T_1	T_2	T_3
Water temperature (°C)	33.46 ± 0.22^{a}	33.43 ± 0.19^{a}	33.17 ± 0.12^{a}
Transparency (cm)	32.97 ± 0.03^{a}	31.00 ± 0.58^{b}	33.00 ± 0.58^{a}
DO (mg/l)	5.38 ± 0.06^{a}	5.20 ± 0.09^{ab}	5.03 ± 0.09^{b}
pH	7.23 ± 0.12^{a}	7.03 ± 0.03^{a}	7.27 ± 0.18^{a}
Alkalinity (mg/l)	113.33 ± 1.20^{a}	113.67 ± 2.40^{a}	111.00 ± 3.21^{a}
Free CO_2 (mg/l)	2.67 ± 0.09^{a}	2.73 ± 0.09^{a}	2.90 ± 0.06^{a}

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

Table-5.7: Variations in the mean values of water quality parameters under different treatments at 6th fortnight

Parameters \ Treatments	T_1	T_2	T_3
Water temperature (°C)	33.27 ± 0.12^{a}	33.43 ± 0.18^{a}	33.47 ± 0.18^{a}
Transparency (cm)	34.33 ± 0.33^{a}	32.33 ± 0.88^{a}	33.00 ± 0.58^{a}
DO (mg/l)	5.67 ± 0.09^{a}	5.50 ± 0.06^{a}	5.20 ± 0.06^{b}
pH	7.12 ± 0.06^{a}	7.20 ± 0.06^{a}	7.05 ± 0.03^{a}
Alkalinity (mg/l)	109.00 ± 1.53^{a}	107.67 ± 1.45^{a}	107.67 ± 1.33^{a}
Free CO_2 (mg/l)	2.03 ± 0.03^{a}	2.10 ± 0.06^{a}	2.17 ± 0.07^{a}

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

Table-5.8: Variations in the mean values of water quality parameters under different treatments at 7th fortnight

Parameters \ Treatments	T_1	T_2	T_3
Water temperature (°C)	32.13±0.09^a	32.47±0.20^a	32.30±0.12^a
Transparency (cm)	32.00±0.58^b	34.67±0.33^a	34.00±0.58^a
DO (mg/l)	5.17±0.12^a	5.10±0.06^a	5.00±0.06^a
pH	6.97±0.09^a	7.00±0.06^a	6.93±0.07^a
Alkalinity (mg/l)	112.67±0.88^a	107.00±1.53^b	113.00±1.15^a
Free CO_2 (mg/l)	2.63±0.07^a	2.68±0.02^a	2.80±0.06^a

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

Table-5.9: Variations in the mean values of water quality parameters under different treatments at 8th fortnight

Parameters \ Treatments	T_1	T_2	T_3
Water temperature (°C)	32.47±0.20^a	32.20±0.15^a	32.27±0.09^a
Transparency (cm)	31.00±0.58^a	31.00±0.58^a	30.33±0.88^a
DO (mg/l)	5.10±0.06^a	5.07±0.12^a	5.00±0.06^a
pH	7.27±0.09^a	7.03±0.12^a	7.07±0.12^a
Alkalinity (mg/l)	108.67±1.86^a	111.33±1.20^a	108.67±1.76^a
Free CO_2 (mg/l)	2.47±0.12^b	3.01±0.07^a	2.90±0.06^a

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

Table-5.10: Variations in the mean values of water quality parameters under different treatments at 9th fortnight

Treatments / Parameters	T_1	T_2	T_3
Water temperature (°C)	31.39±0.09[a]	31.33±0.18[a]	31.23±0.12[a]
Transparency (cm)	33.00±0.58[a]	31.67±0.33[a]	33.00±1.15[a]
DO (ppm)	5.10±0.06[a]	5.07±0.12[a]	5.03±0.03[a]
pH	7.20±0.06[a]	7.03±0.03[a]	7.10±0.15[a]
Alkalinity (ppm)	115.33±0.88[a]	112.67±2.03[a]	107.67±0.88[b]
Free CO_2 (ppm)	2.37±0.09[a]	2.46±0.09[a]	2.52±0.03[a]

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

Table-5.11: Variations in the mean values of water quality parameters under different treatments at 10th fortnight

Treatments / Parameters	T_1	T_2	T_3
Water temperature (°C)	31.47±0.09[a]	31.33±0.03[a]	31.30±0.17[a]
Transparency (cm)	32.33±0.88[a]	31.33±0.88[a]	32.33±1.45[a]
DO (mg/l)	5.33±0.12[a]	5.17±0.09[a]	5.13±0.09[a]
pH	7.17±0.12[a]	7.33±0.12[a]	7.13±0.09[a]
Alkalinity (mg/l)	115.00±2.31[a]	106.33±1.76[b]	110.67±0.88[ab]
Free CO_2 (mg/l)	2.70±0.06[b]	2.95±0.03[ab]	3.13±0.07[a]

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

Table-5.12: Variations in the mean values of water quality parameters under different treatments at 11th fortnight

Parameters \ Treatments	T_1	T_2	T_3
Water temperature (°C)	30.53±0.09^a	30.37±0.09^a	30.17±0.27^a
Transparency (cm)	34.00±0.58^a	32.33±0.67^{ab}	31.33±0.33^b
DO (mg/l)	5.20±0.12^a	5.10±0.06^a	5.07±0.07^a
pH	7.00±0.06^a	7.07±0.03^a	7.07±0.07^a
Alkalinity (mg/l)	110.33±3.38^a	110.33±0.33^a	115.67±1.76^a
Free CO_2 (mg/l)	2.67±0.09^a	2.73±0.07^a	2.81±0.09^a

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P <0.05$)

Table-5.13: Variations in the mean values of water quality parameters under different treatments at 12th fortnight

Parameters \ Treatments	T_1	T_2	T_3
Water temperature (°C)	30.73±0.12^a	30.17±0.27^a	30.13±0.15^a
Transparency (cm)	33.00±1.53^a	33.67±0.88^a	32.67±0.33^a
DO (mg/l)	5.70±0.06^a	5.67±0.03^a	5.57±0.03^a
pH	7.57±0.07^a	7.40±0.06^a	7.57±0.03^a
Alkalinity (mg/l)	108.67±1.20^a	111.67±1.45^a	107.33±1.20^a
Free CO_2 (mg/l)	3.05±0.06^a	3.13±0.09^a	3.18±0.07^a

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P <0.05$)

5.4.1.2 Mean variations

The variations in the mean vales of different water quality parameters in different treatments by the total of all fortnights are presented in table 5.14 and fig. 5.1.

Water temperature

During the study period the mean values of water temperature ranged from 31.76±0.30 to 31.93±0.27 °C. The minimum value was recorded in treatment T_3 whereas the maximum value was recorded in treatment T_1.

Water transparency

The mean value of water transparency varied from 32.25±0.34 to 33.11±0.33 cm. The minimum value was recorded in treatment T_2 whereas the maximum value was recorded in treatment T_1.

Dissolved Oxygen (DO)

The mean value of DO varied from 5.32±0.09 to 5.41±0.09 mg/l. The minimum value was recorded in treatment T_3 whereas the maximum value was recorded in treatment T_1.

Hydrogen ion concentration (pH)

The mean value of water pH varied from 7.25±0.07 to 7.35±0.09. The minimum value was recorded in treatment T_2 whereas the maximum value was recorded in treatment T_1.

Alkalinity

The mean value of total alkalinity varied from 110.81±0.85 to 112.56±0.94 mg/l. The minimum value was recorded in treatment T_3 whereas the maximum value was recorded in treatment T_1.

Free carbon-dioxide (CO_2)

The mean value of free CO_2 varied from 2.64±0.07 to 2.87±0.08. The minimum value was recorded in treatment T_1 whereas the maximum value was recorded in treatment T_3.

No significant difference was found among the treatments for mean values of water quality parameters.

Table 5.14: Variations in the mean values of water quality parameters under different treatments during study period

Treatments / Parameters	T_1	T_2	T_3
Water temperature (°C)	31.93±0.27[a]	31.84±0.31[a]	31.76±0.30[a]
Transparency (cm)	33.11±0.33[a]	32.25±0.34[a]	32.61±0.29[a]
DO (mg/l)	5.41±0.09[a]	5.35±0.11[a]	5.32±0.09[a]
pH	7.35±0.09[a]	7.25±0.07[a]	7.29±0.10[a]
Alkalinity (mg/l)	112.56±0.94[a]	111.78±1.32[a]	110.81±0.85[a]
Free CO_2 (mg/l)	2.64±0.07[a]	2.81±0.09[a]	2.87±0.08[a]

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

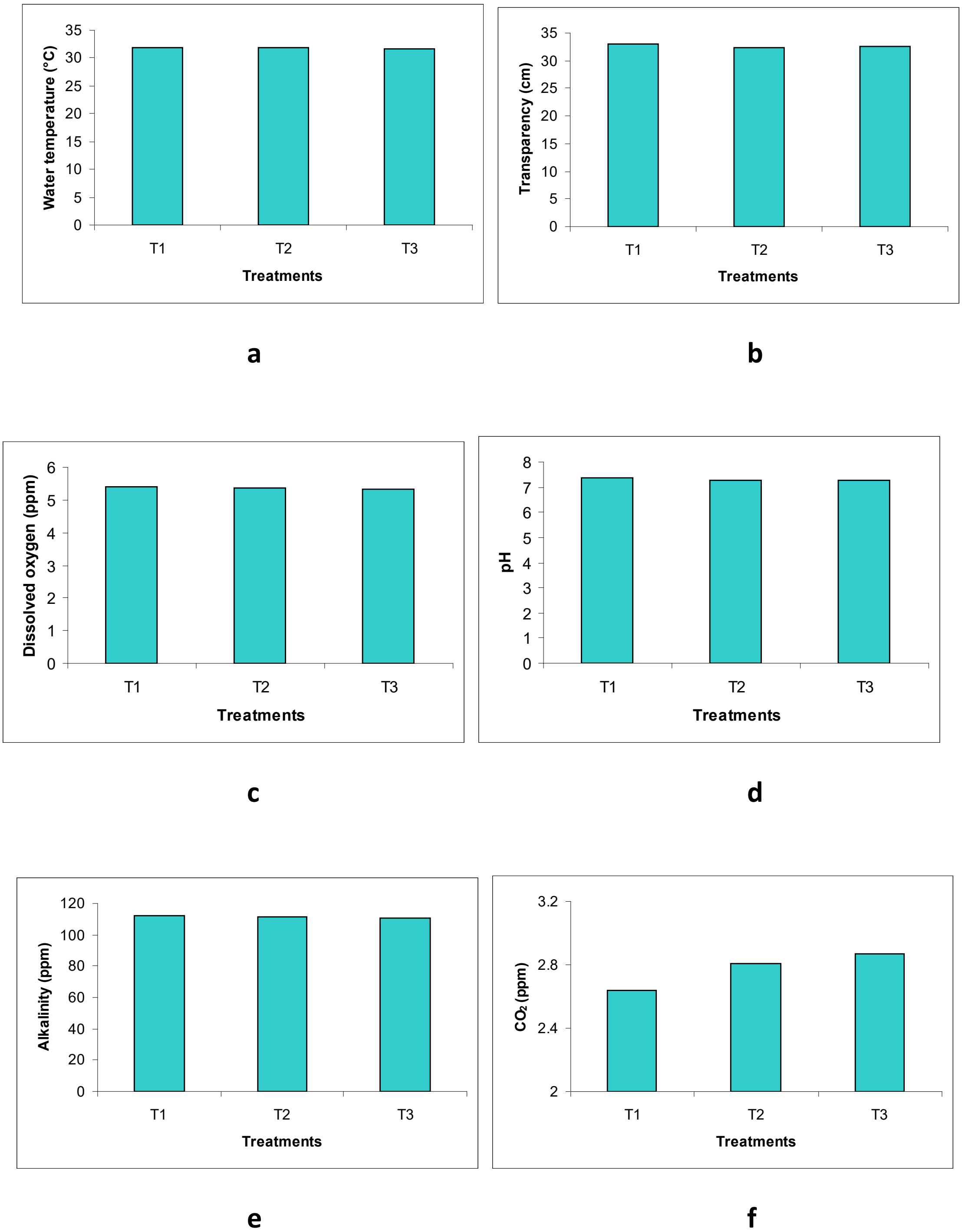


Fig. 5.1: Variations in the mean values of water quality parameters (a, Water temperature; b, transparency; c, DO; d, pH; e, alkalinity; f, free CO_2) under different treatments during study period.

5.4.2: Growth of fishes

5.4.2.1: Monthly variations

Specific growth rate (SGR, %, bwd^{-1})

The specific growth rate (%, bwd^{-1}) varied with *H. molitrix* from 0.53±0.01 (T_2 at 6th month) to 2.68±0.02 (T_1 at 1st month), *C. catla* from 0.48±0.003 (T_3 at 6th month) to 2.63±0.003 (T_1 at 1st month), *L. rohita* from 0.39±0.01 (T_2 at 6th month) to 2.04±0.07 (T_1 at 1st month), *C. cirrhosus* from 0.39±0.02 (T_2 at 6th month) to 2.30±0.11 (T_2 at 1st month), *C. carpio* from 0.50±0.03 (T_3 at 6th month) to 2.28±0.16 (T_1 at 1st month), *C. idella* from 0.49±0.01 (T_2 at 6th month) to 2.98±0.04 (T_1 at 1st month) and *B. gonionotus* from 0.46±0.02 (T_3 at 6th month) to 3.42±0.07 (T_1 at 1st month) (Table 5.15 to 5.20).

Among the species, the highest SGR was observed in *B. gonionotus* as 3.42±0.07 %, bwd^{-1} and the lowest was in *L. rohita* as 0.39±0.01 %, bwd^{-1}.

The lowest combined SGR value was found as 0.47±0.022 (T_2 at 6th month) and the highest combined SGR was found as 2.60±0.18 (T_1 at 1st month). The highest SGR value was found in the month of April and the lowest value was found in the month of September for all the species.

Significant variation was found in 1st month (April) for all species.

Table-5.15: Variations in the mean values of SGR (%, bwd^{-1}) of fishes under different treatments at 1st month (April)

Species \ Treatments	T_1	T_2	T_3
H. molitrix	$2.68±0.02^{a}$	$2.57±0.02^{b}$	$2.48±0.02^{c}$
C. catla	$2.63±0.03^{a}$	$2.50±0.03^{b}$	$2.40±0.02^{c}$
L. rohita	$2.04±0.07^{a}$	$1.86±0.04^{b}$	$1.76±0.03^{b}$
C. cirrhosus	$2.20±0.15^{a}$	$2.30±0.11^{a}$	$1.93±0.12^{a}$
C. carpio	$2.28±0.16^{a}$	$2.02±0.06^{a}$	$2.12±0.03^{a}$
C. idella	$2.98±0.04^{a}$	$2.81±0.06^{ab}$	$2.74±0.07^{b}$
B. gonionotus	$3.42±0.07^{a}$	$3.21±0.04^{ab}$	$3.07±0.09^{b}$
All species	$2.60±0.18^{a}$	$2.47±0.17^{ab}$	$2.36±0.17^{b}$

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P <0.05$)

Table-5.16: Variations in the mean values of SGR (%, bwd^{-1}) of fishes under different treatments at 2nd month (May)

Species \ Treatments	T_1	T_2	T_3
H. molitrix	$1.53±0.02^{a}$	$1.48±0.01^{b}$	$1.46±0.01^{b}$
C. catla	$1.50±0.01^{a}$	$1.43±0.02^{b}$	$1.43±0.01^{b}$
L. rohita	$1.31±0.01^{a}$	$1.23±0.06^{a}$	$1.29±0.01^{a}$
C. cirrhosus	$1.42±0.05^{a}$	$1.24±0.04^{b}$	$1.30±0.03^{ab}$
C. carpio	$1.70±0.11^{a}$	$1.74±0.08^{a}$	$1.59±0.07^{a}$
C. idella	$1.59±0.05^{a}$	$1.59±0.02^{a}$	$1.53±0.01^{a}$
B. gonionotus	$1.70±0.05^{a}$	$1.73±0.02^{a}$	$1.64±0.04^{a}$
All species	$1.54±0.05^{a}$	$1.49±0.08^{a}$	$1.46±0.05^{a}$

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P <0.05$)

Table-5.17: Variations in the mean values of SGR (%, bwd^{-1}) of fishes under different treatments at 3rd month (June)

Treatments / Species	T_1	T_2	T_3
H. molitrix	1.11±0.01^{a}	1.07±0.003^{b}	1.05±0.01^{b}
C. catla	1.17±0.02^{a}	1.17±0.03^{a}	1.18±0.01^{a}
L. rohita	1.01±0.03^{a}	1.04±0.02^{a}	1.01±0.01^{a}
C. cirrhosus	1.12±0.04^{a}	0.98±0.08^{b}	0.97±0.03^{b}
C. carpio	1.25±0.03^{a}	1.23±0.04^{a}	1.09±0.03^{b}
C. idella	1.17±0.02^{a}	1.11±0.02^{a}	1.02±0.03^{b}
B. gonionotus	1.36±0.05^{a}	1.31±0.05^{a}	1.31±0.11^{a}
All species	1.17±0.04^{a}	1.13±0.02^{a}	1.09±0.32^{a}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-5.18: Variations in the mean values of SGR (%, bwd^{-1}) of fishes under different treatments at 4th month (July)

Treatments / Species	T_1	T_2	T_3
H. molitrix	0.83±0.003^{a}	0.81±0.01^{b}	0.80±0.003^{b}
C. catla	0.85±0.02^{a}	0.88±0.02^{a}	0.87±0.01^{a}
L. rohita	0.82±0.02^{a}	0.80±0.01^{a}	0.81±0.02^{a}
C. cirrhosus	0.89±0.02^{a}	0.80±0.02^{b}	0.74±0.01^{c}
C. carpio	0.89±0.03^{a}	0.89±0.05^{a}	0.92±0.02^{a}
C. idella	0.84±0.04^{a}	0.83±0.02^{a}	0.83±0.02^{a}
B. gonionotus	0.99±0.01^{a}	1.00±0.01^{a}	1.05±0.03^{a}
All species	0.87±0.02^{a}	0.86±0.03^{a}	0.86±0.04^{a}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-5.19: Variations in the mean values of SGR (%, bwd^{-1}) of fishes under different treatments at 5th month (August)

Treatments / Species	T_1	T_2	T_3
H. molitrix	0.66 ± 0.003^{a}	0.65 ± 0.01^{a}	0.64 ± 0.01^{a}
C. catla	0.59 ± 0.003^{a}	0.59 ± 0.01^{a}	0.58 ± 0.003^{a}
L. rohita	0.47 ± 0.02^{a}	0.50 ± 0.02^{a}	0.48 ± 0.01^{a}
C. cirrhosus	0.54 ± 0.01^{ab}	0.56 ± 0.01^{a}	0.51 ± 0.02^{b}
C. carpio	0.64 ± 0.02^{a}	0.63 ± 0.01^{a}	0.60 ± 0.01^{a}
C. idella	0.61 ± 0.01^{a}	0.60 ± 0.01^{a}	0.61 ± 0.003^{a}
B. gonionotus	0.59 ± 0.01^{a}	0.59 ± 0.02^{a}	0.59 ± 0.02^{a}
All species	0.59 ± 0.024^{a}	0.59 ± 0.018^{a}	0.57 ± 0.022^{a}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-5.20: Variations in the mean values of SGR (%, bwd^{-1}) of fishes under different treatments at 6th month (September)

Treatments / Species	T_1	T_2	T_3
H. molitrix	0.54 ± 0.003^{a}	0.53 ± 0.01^{a}	0.55 ± 0.01^{a}
C. catla	0.51 ± 0.003^{a}	0.50 ± 0.02^{a}	0.48 ± 0.003^{a}
L. rohita	0.43 ± 0.01^{a}	0.39 ± 0.01^{a}	0.43 ± 0.01^{a}
C. cirrhosus	0.44 ± 0.03^{a}	0.39 ± 0.02^{a}	0.42 ± 0.01^{a}
C. carpio	0.50 ± 0.03^{a}	0.52 ± 0.02^{a}	0.50 ± 0.03^{a}
C. idella	0.50 ± 0.01^{a}	0.49 ± 0.01^{a}	0.53 ± 0.02^{a}
B. gonionotus	0.50 ± 0.01^{a}	0.47 ± 0.01^{a}	0.46 ± 0.02^{a}
All species	0.49 ± 0.015^{a}	0.47 ± 0.022^{a}	0.48 ± 0.018^{a}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Monthly weight gain (g/month)

The weight gain (g/month) varied with *H. molitrix* from 66.33±0.88 g (T_3 at 1st month) to 84.00±1.53 g (T_1 at 4th month), *C. catla* from 68.33±0.88g (T_3 at 1st month) to 94.33±1.76 g (T_1 at 3rd month), *L. rohita* from 38.67±1.33 g (T_3 at 5th month) to 59.67±0.88 g (T_1 at 4th month), *C. cirrhosus* from 42.67±2.33 g (T_3 at 5th month) to 73.33±2.40 g (T_1 at 4th month), *C. carpio* from 51.00±2.08 (T_2 at 1st month) to 91.67±3.28 g (T_1 at 3rd month), *C. idella* from 89.00±3.21 (T_3 at 5th month) to 115.67±1.76 g (T_1 at 3rd month) and *B. gonionotus* from 32.33±1.33 (T_3 at 6th month) to 53.33±0.33 g (T_1 at 4th month) (Table 5.21 – 5.26).

Among the species, the highest monthly weight gain was observed in *C. idella* as 115.67±1.76 g and the lowest was in *B. gonionotus* as 32.33±1.33 g.

The lowest combined weight gain value was found as 56.81±7.29 g (T_3 at 1st month) and the highest combined weight was found as 80.62±7.64 g (T_1 at 4th month). The highest weight gain was found in the month of July and the lowest value was found in the month of April for all the species.

Significant variation in monthly weight gain was found under different treatments in all the months for all species.

Table-5.21: Variations in the mean weight gain (g/month) of fishes under different treatments at 1st month (April)

Treatments / Species	T_1	T_2	T_3
H. molitrix	74.33±0.67[a]	69.67±0.88[b]	66.33±0.88[c]
C. catla	78.33±1.20[a]	72.67±1.20[b]	68.33±0.88[c]
L. rohita	49.00±2.31[a]	43.33±1.20[b]	40.33±0.88[b]
C. cirrhosus	54.33±4.81[a]	57.67±3.84[a]	45.67±3.84[a]
C. carpio	60.00±6.08[a]	51.00±2.08[a]	54.33±1.20[a]
C. idella	101.00±2.08[a]	92.67±2.96[ab]	89.33±3.48[b]
B. gonionotus	39.33±1.20[a]	35.67±0.67[ab]	33.33±1.45[b]
All species	65.19±7.89[a]	60.38±7.36[b]	56.81±7.29[c]

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-5.22: Variations in the mean weight gain (g/month) of fishes under different treatments at 2nd month (May)

Treatments / Species	T_1	T_2	T_3
H. molitrix	78.33±1.76[a]	72.33±1.20[b]	69.33±0.67[b]
C. catla	81.67±1.20[a]	73.67±1.76[b]	71.67±0.88[b]
L. rohita	51.33±1.45[a]	45.33±2.03[b]	46.67±0.33[ab]
C. cirrhosus	59.67±0.88[a]	52.00±1.73[b]	49.33±1.20[b]
C. carpio	80.00±3.21[a]	77.00±4.04[a]	70.67±3.38[a]
C. idella	104.33±3.18[a]	99.67±0.67[ab]	92.67±2.73[b]
B. gonionotus	40.67±0.88[a]	39.33±0.33[ab]	35.33±2.03[b]
All species	70.86±8.16[a]	65.62±8.00[b]	62.24±7.35[c]

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-5.23: Variations in the mean weight gain (g/month) of fishes under different treatments at 3rd month (June)

Treatments / Species	T_1	T_2	T_3
H. molitrix	83.67±1.86^{a}	76.67±0.88^{b}	72.67±0.88^{b}
C. catla	94.33±1.76^{a}	88.67±2.40^{ab}	87.33±0.88^{b}
L. rohita	56.33±1.76^{a}	53.67±1.33^{a}	51.67±0.88^{a}
C. cirrhosus	69.00±4.36^{a}	57.33±3.48^{b}	51.67±1.45^{b}
C. carpio	91.67±3.28^{a}	84.67±2.33^{a}	72.00±2.08^{b}
C. idella	115.67±1.76^{a}	104.33±2.19^{b}	91.00±4.51^{c}
B. gonionotus	51.33±2.03^{a}	46.67±2.03^{b}	43.67±3.53^{b}
All species	80.29±8.63^{a}	73.14±8.00^{b}	67.14±7.00^{c}

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

Table-5.24: Variations in the mean weight gain (g/month) of fishes under different treatments at 4th month (July)

Treatments / Species	T_1	T_2	T_3
H. molitrix	84.00±1.53^{a}	76.67±0.33^{b}	73.33±0.67^{b}
C. catla	92.33±1. 86^{a}	91.33±1.76^{a}	87.33±1.45^{a}
L. rohita	59.67±0.88^{a}	54.67±0.88^{b}	54.33±1.76^{b}
C. cirrhosus	73.33±2.40^{a}	61.33±1.86^{b}	51.33±1.86^{c}
C. carpio	89.67±1.45^{a}	83.67±4.84^{a}	82.00±1.53^{a}
C. idella	112.00±4.73^{a}	103.67±3.18^{ab}	96.33±3.71^{b}
B. gonionotus	53.33±0.33^{a}	50.33±0.88^{b}	49.33±0.67^{b}
All species	80.62±7.64^{a}	74.52±7.52^{b}	70.57±7.18^{c}

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

Table-5.25: Variations in the mean weight gain (g/month) of fishes under different treatments at 5th month (August)

Treatments / Species	T_1	T_2	T_3
H. molitrix	83.00 ± 2.00^{a}	76.33 ± 0.33^{b}	73.00 ± 0.58^{b}
C. catla	80.00 ± 1.15^{a}	76.00 ± 2.31^{ab}	71.67 ± 1.20^{b}
L. rohita	41.67 ± 1.20^{a}	41.00 ± 1.53^{a}	38.67 ± 1.33^{a}
C. cirrhosus	55.67 ± 2.40^{a}	52.00 ± 1.00^{a}	42.67 ± 2.33^{b}
C. carpio	80.67 ± 1.20^{a}	74.00 ± 3.21^{ab}	67.00 ± 1.73^{b}
C. idella	101.00 ± 2.08^{a}	93.00 ± 2.52^{ab}	89.00 ± 3.21^{b}
B. gonionotus	40.00 ± 0.58^{a}	37.67 ± 1.45^{ab}	35.67 ± 0.67^{b}
All species	68.86 ± 8.79^{a}	64.29 ± 7.87^{b}	59.67 ± 7.78^{c}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-5.26: Variations in the mean weight gain (g/month) of fishes under different treatments at 6th month (September)

Treatments / Species	T_1	T_2	T_3
H. molitrix	81.67 ± 2.03^{a}	74.67 ± 0.88^{b}	73.33 ± 2.03^{b}
C. catla	81.67 ± 0.33^{a}	75.67 ± 1.76^{b}	69.67 ± 1.45^{c}
L. rohita	43.33 ± 0.88^{a}	37.00 ± 1.53^{b}	39.67 ± 0.88^{ab}
C. cirrhosus	52.33 ± 2.19^{a}	42.67 ± 3.18^{b}	40.00 ± 1.15^{b}
C. carpio	75.67 ± 3.53^{a}	72.67 ± 2.19^{a}	65.33 ± 3.18^{a}
C. idella	97.67 ± 2.33^{a}	89.33 ± 1.20^{b}	91.33 ± 1.33^{b}
B. gonionotus	39.67 ± 0.88^{a}	35.33 ± 0.88^{b}	32.33 ± 1.33^{b}
All species	67.43 ± 8.41^{a}	61.05 ± 8.33^{b}	58.81 ± 8.24^{c}

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

5.4.2.2: Mean variations

Variations in the mean values of growth parameters of fishes under different treatments are shown in table 5.27 to 5.31, fig. 5.2 to 5.4 and plate 5.5.

SGR (%, bwd^{-1})

The specific growth rate (SGR, %, bwd^{-1}) varied with *H. molitrix* from 1.16±0.30 (T_3) to 1.23±0.32 (T_1), *C. catla* from 1.16±0.29 g (T_3) to 1.21±0.32 (T_1), *L. rohita* from 0.96±0.21 (T_3) to 1.01±0.25 (T_1), *C. cirrhosus* from 0.98±0.23 (T_3) to 1.10±0.26 (T_1), *C. carpio* from 1.14±0.25 (T_3) to 1.21±0.28 (T_1), *C. idella* from 1.21±0.34 (T_3) to 1.28±0.38 (T_1) and *B. gonionotus* from 1.35±0.39 (T_3) to 1.43±0.44 (T_1).

Among the species the highest SGR was observed as 1.43±0.44 %, bwd^{-1} in *B. gonionotus* and the lowest was in *L. rohita* as 0.96±0.21 %, bwd^{-1}.

The lowest combined SGR value was found as 1.14±0.05 (T_3) and the highest combined SGR as 1.21±0.05 (T_1).

Significant difference was found among the treatments for the mean values of SGR of all the species.

Weight gain (g/month)

Mean weight gain (g/month) varied with *H. molitrix* from 71.33±1.18 g (T_3) to 80.83±1.55 g (T_1), *C. catla* from 76.00±3.62 g (T_3) to 84.72±2.78g (T_1), *L. rohita* from 45.22±2.73 g (T_3) to 50.22±2.89g (T_1), *C. cirrhosus* from 46.78±1.96 g (T_3) to 60.72±3.49 g (T_1), *C. carpio* from 68.56±3.71 g (T_3) to 79.61±4.65 g (T_1), *C. idella* from 91.61±1.09 g (T_3) to 105.28±2.88 g (T_1) and *B. gonionotus* from 38.28±2.75 g (T_3) to 44.06±2.64 g (T_1).

Among the species the highest weight gain was observed as 105.28±2.88 g in *C. idella* and the lowest was in *B. gonionotus* as 38.28±2.75 g.

The lowest mean weight gain was found as 62.54±7.36 g (T_3) and the highest weight gain as 72.21±8.15 g (T_1) for all the species.

Significant difference was found among the treatments for the mean values of weight gain of all the species.

Final Weight (g)

The mean final weight (g) varied with *H. molitrix* from 468.00±24.01 (T_3) to 545.00±9.61 g (T_1), *C. catla* from 521.00±6.25 (T_3) to 573.33±3.71 g (T_1), *L. rohita* from 329.33±3.71 (T_3) to 359.33±3.18 g (T_1), *C. cirrhosus* from 338.67±10.17 (T_3) to 422.33±11.61 g (T_1), *C. carpio* from 472.33±3.71 (T_3) to 538.67±3.84 g (T_1), *C. idella* from 619.67±16.48 (T_3) to 701.67±7.22 g (T_1) and *B. gonionotus* from 251.33±4.06 (T_3) to 287.67±1.67 g (T_1).

Among the species the highest final weight was observed as 701.67±7.22 g in *C. idella* and the lowest was in *B. gonionotus* as 251.33±4.06g.

The lowest mean final weight was found as 3000.33±31.25 g (T_3) and the highest final weight as 3428.00±25.35 g (T_1) for all the species.

Significant difference was found among the treatments for the mean values of final weight of all the species.

Survival rate (%)

The survival rate (%) varied with *H. molitrix* from 85.33±1.17 (T_3) to 90.33±2.91% (T_1), *C. catla* from 80.87±0.58 (T_3) to 83.63±0.75% (T_1), *L. rohita* from 83.10±2.18 (T_1) to 84.13±1.21% (T_2), *C. cirrhosus* from 85.50±0.58 (T_2) to 91.53±1.13% (T_1), *C. carpio* from 93.07±0.81% (T_2) to 94.53±0.61% (T_1), *C. idella* from 85.07±0.96 (T_2) to 86.37±0.52% (T_1) and *B. gonionotus* from 80.50±1.15 (T_1) to 81.73±0.79% (T_3).

Among the species the highest survival rate was observed as 94.53±0.61% in *C. carpio* and the lowest was in *B. gonionotus* as 80.50±1.15%.

The lowest mean survival rate was found as 85.20±1.55% g (T_3) and the highest survival rate as 87.14±1.94% (T_1) for all the species.

No significant difference was found among the treatments for the mean values of survival rate of all the species except *C. cirrhosus*.

Yield (Kg/ha/6 months)

The individual fish yield (Kg/ha/6 months) varied with *H. molitrix* from 969.00±17.16 (T_1) to 982.67±50.35 (T_3), *C. catla* from 241.00±1.53 (T_1) to 411.67±4.81 (T_3), *L. rohita* from 603.67±5.21 (T_1) to 781.00±8.62 (T_3), *C. cirrhosus* from 375.67±10.17 (T_1) to 426.33±12.84 (T_3), *C. carpio* from 252.67±1.86 (T_1) to 419.67±3.38 (T_3), *C. idella* from 520.33±13.87 (T_3) to 884.00±9.07 (T_1) and *B. gonionotus* from 496.67±8.11 (T_3) to 568.33±3.33 (T_1).

Among the species the highest yield was observed as 982.67±50.35 (T_3) kg/ha/6 months in *H. molitrix* and the lowest was in *C. catla* as 241.00±1.53 (T_1) kg/ha/6 months.

The lowest total fish yield (Kg/ha/6 months) was found as 3894.33±18.00 (T_1) and the highest total yield was found as 4038.33±84.41 (T_3). Significant difference in total yield was found among the treatments.

Significant difference was found among the treatments for the mean values of yield of all the species.

Table-5.27: Variations in the mean SGR (%, bwd^{-1}) of fishes under different treatments during the study period

Treatments / Species	T_1	T_2	T_3
H. molitrix	$1.23±0.32^a$	$1.19±0.31^b$	$1.16±0.30^b$
C. catla	$1.21±0.32^a$	$1.18±0.30^a$	$1.16±0.29^a$
L. rohita	$1.01±0.25^a$	$0.97±0.22^a$	$0.96±0.21^a$
C. cirrhosus	$1.10±0.26^a$	$1.01±0.28^b$	$0.98±0.23^b$
C. carpio	$1.21±0.28^a$	$1.17±0.25^a$	$1.14±0.25^a$
C. idella	$1.28±0.38^a$	$1.22±0.35^b$	$1.21±0.34^b$
B. gonionotus	$1.43±0.44^a$	$1.39±0.41^a$	$1.35±0.39^a$
All species	$1.21±0.05^a$	$1.16±0.05^b$	$1.14±0.05^b$

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-5.28: Variations in the mean weight gain (g/6 month) of fishes under different treatments during the study period.

Treatments / Species	T_1	T_2	T_3
H. molitrix	$80.83±1.55^a$	$74.39±1.17^b$	$71.33±1.18^b$
C. catla	$84.72±2.78^a$	$79.67±3.32^a$	$76.00±3.62^a$
L. rohita	$50.22±2.89^a$	$45.83±2.87^a$	$45.22±2.73^a$
C. cirrhosus	$60.72±3.49^a$	$53.83±2.67^{ab}$	$46.78±1.96^b$
C. carpio	$79.61±4.65^a$	$73.84±4.99^a$	$68.56±3.71^a$
C. idella	$105.28±2.88^a$	$97.11±2.57^b$	$91.61±1.09^b$
B. gonionotus	$44.06±2.64^a$	$40.83±2.54^a$	$38.28±2.75^a$
All species	$72.21±8.15^a$	$66.50±7.67^{ab}$	$62.54±7.36^b$

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)

Table-5.29: Variations in the mean final weight (g) of fishes under different treatments during the study period.

Species \ Treatments	T_1	T_2	T_3
H. molitrix	545.00±9.61[a]	506.33±2.73[ab]	468.00±24.01[b]
C. catla	573.33±3.71[a]	543.00±5.57[b]	521.00±6.25[c]
L. rohita	359.33±3.18[a]	333.00±4.00[b]	329.33±3.71[b]
C. cirrhosus	422.33±11.61[a]	381.00±7.00[b]	338.67±10.17[c]
C. carpio	538.67±3.84[a]	504.00±11.15[b]	472.33±3.71[c]
C. idella	701.67±7.22[a]	652.67±10.27[b]	619.67±16.48[b]
B. gonionotus	287.67±1.67[a]	267.00±2.52[b]	251.33±4.06[c]
All species	3428.00±11.21[a]	3187.00±14.05[b]	3000.33±13.25[b]

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

Table-5.30: Variations in the mean survival rate (%) of fishes under different treatments during the study period.

Species \ Treatments	T_1	T_2	T_3
H. molitrix	90.33±2.91[a]	85.50±0.76[a]	85.33±1.17[a]
C. catla	83.63±0.75[a]	83.00±1.26[a]	80.87±0.58[a]
L. rohita	83.10±2.18[a]	84.13±1.21[a]	83.87±1.02[a]
C. cirrhosus	91.53±1.13[a]	85.50±0.58[b]	85.73±0.62[b]
C. carpio	94.53±0.61[a]	93.07±0.81[a]	93.47±1.55[a]
C. idella	86.37±0.52[a]	85.07±0.96[a]	85.43±1.16[a]
B. gonionotus	80.50±1.15[a]	80.73±1.30[a]	81.73±0.79[a]
All species	87.14±1.94[a]	85.29±1.45[a]	85.20±1.55[a]

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

Table-5.31: Variations in the mean yield (kg/ha) of fishes under different treatments during the study period.

Treatments / Species	T_1	T_2	T_3
H. molitrix	969.00±17.16[a] (24.88%)	979.00±5.13[a] (24.74%)	982.67±50.35[a] (24.33%)
C. catla	241.00±1.53[c] (6.19%)	330.33±3.38[b] (8.35%)	411.67±4.81[a] (10.19%)
L. rohita	603.67±5.21[c] (15.50%)	699.00±8.50[b] (17.67%)	781.00±8.62[a] (19.34%)
C. cirrhosus	375.67±10.17[b] (9.65%)	400.00±7.57[ab] (10.11%)	426.33±12.84[a] (10.56%)
C. carpio	252.67±1.86[c] (6.49%)	336.00±7.37[b] (8.49%)	419.67±3.38[a] (10.39%)
C. idella	884.00±9.07[a] (22.70%)	684.67±10.81[b] (17.30%)	520.33±13.87[c] (12.88%)
B. gonionotus	568.33±3.33[a] (14.59%)	527.67±4.70[b] (13.34%)	496.67±8.11[c] (12.30%)
Total yield (Kg/ha/6 months)	3894.33±18.00[c]	3956.67±43.72[b]	4038.33±84.41[a]
Total yield (Kg/ha/yr)	7788.66±38.69[c]	7913.34±84.23[b]	8076.66±96.35[a]

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

Values in the parentheses means % contribution by individual species to total fish yield under respective treatment.

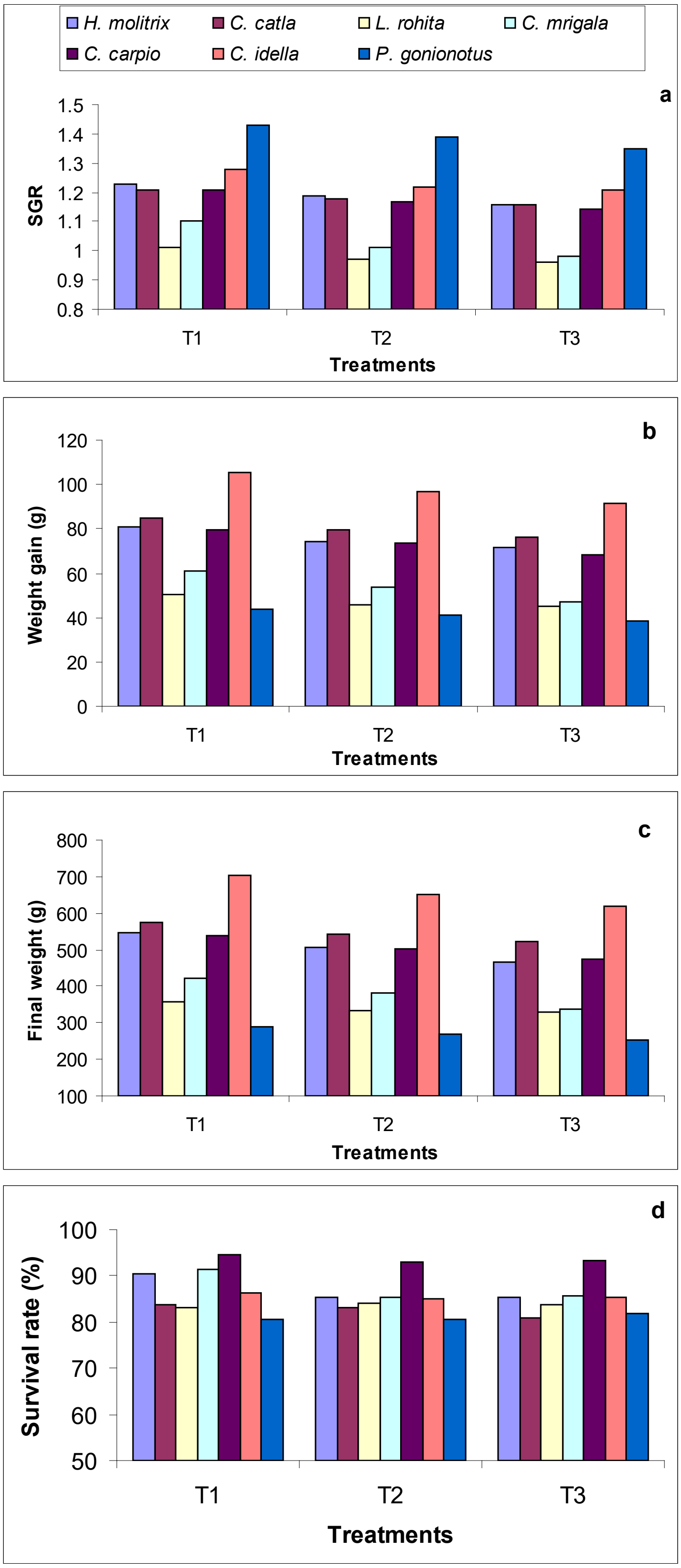


Fig. 5.2. Variations in the mean values of different growth parameters under different treatments during the study period: a; SGR (%, bwd^{-1}), b; weight gain (g), c; final weight (g) and d; survival rate (%)

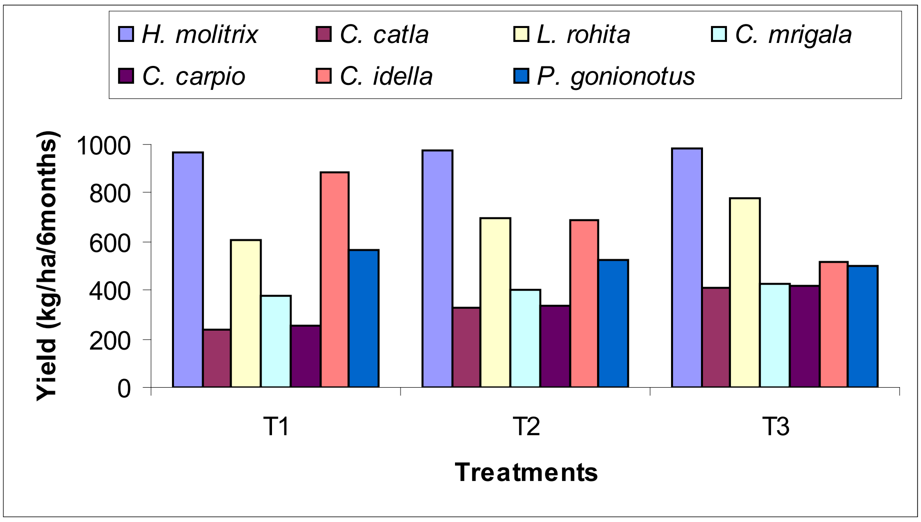


Fig. 5.3: Variations in the mean values of fish yield under different treatments

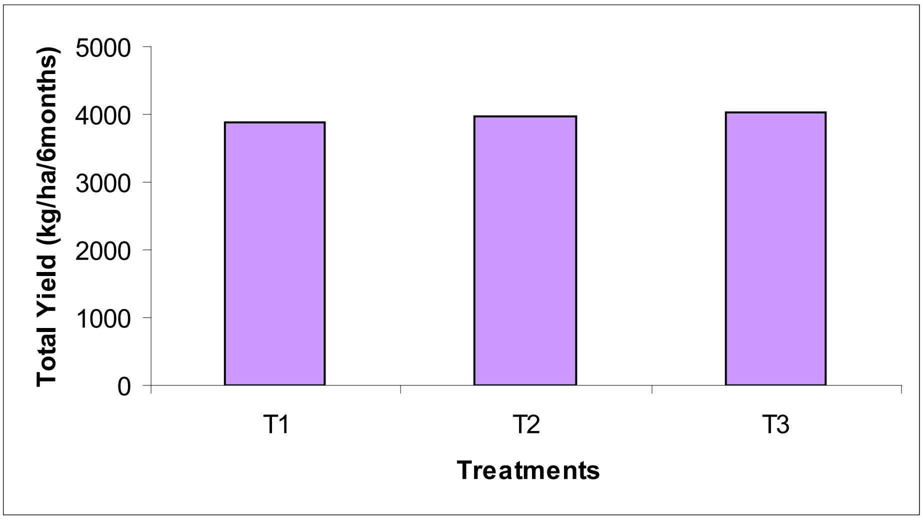


Fig. 5.4: Variations in the mean values of total fish yield under different treatments

Plate 5.5: Harvesting of fishes.

5.4.3: Economics

The economics of fish farming under different treatments are presented in table 5.32 and fig. 5.5.

Total cost significantly varied from 136862.00±606.45 (T_1) to 145754.00±57.35 Tk/ha/6 months (T_3). Gross benefit significantly varied from 384562.35±1890.32 (T_1) to 402667±8862.88 Tk/ha/6 months (T_3). Net benefit significantly varied from 247700.35±1890.32 Tk/ha/6 months (T_1) to 256913.35±8862.88 Tk/ha/6 months (T_3). The Net profit margin significantly varied from 176.31±5.55 (T_3) to 181.00±1.53% (T_1). The CBR significantly varied from 1.76±0.06 (T_3) to 1.81±0.02 (T_1).

Table 5.32: Economics of fish production under different treatments

Components \ Treatments	T_1	T_2	T_3
Lease value (Tk.)	45000.00±0.00^a (32.88%)	45000.00±0.00^a (31.85%)	45000.00±0.00^a (30.87%)
Pond preparation (Tk.)	11480.00±57.74^c (8.39%)	11480.00±98.56^b (8.12%)	11480.00±59.65^a (7.88%)
Fertilizer (Tk.)	26790.00±0.00^a (19.57%)	26790.00±0.00^a (18.96%)	26790.00±0.00^a (18.38%)
Fish seed (Tk.)	33592.00±0.00^a (24.54%)	38038.00±0.00^a (26.92%)	42484.00±0.00^a (29.15%)
Feed (Tk.)	00.00±0.00^a (0.00%)	00.00±0.00^a (0.00%)	00.00±0.00^a (0.00%)
Harvesting cost (Tk.)	20000.00±0.00^a (14.61%)	20000.00±0.00^a (14.15%)	20000.00±0.00^a (13.72%)
Total cost (Tk.)	136862.00±606.45^c	141308.00±57.74^b	145754.00±57.35^a
Gross benefit (Tk.)	384562.35±1890.32^b	392651.95±4590.61^b	402667.35±8862.88^a
Net benefit (Tk.)	247700.35±1890.32^b	251343.95±4590.61^{ab}	256913.35±8862.88^a
Net profit margin (%)	181.00±1.53^a	178.33±2.96^{ab}	176.31±5.55^b
CBR	1.81±0.02^a	1.78±0.03^{ab}	1.76±0.06^b

Figures bearing common letter(s) in a row as superscript do not differ significantly ($P < 0.05$)
% of total cost in parentheses

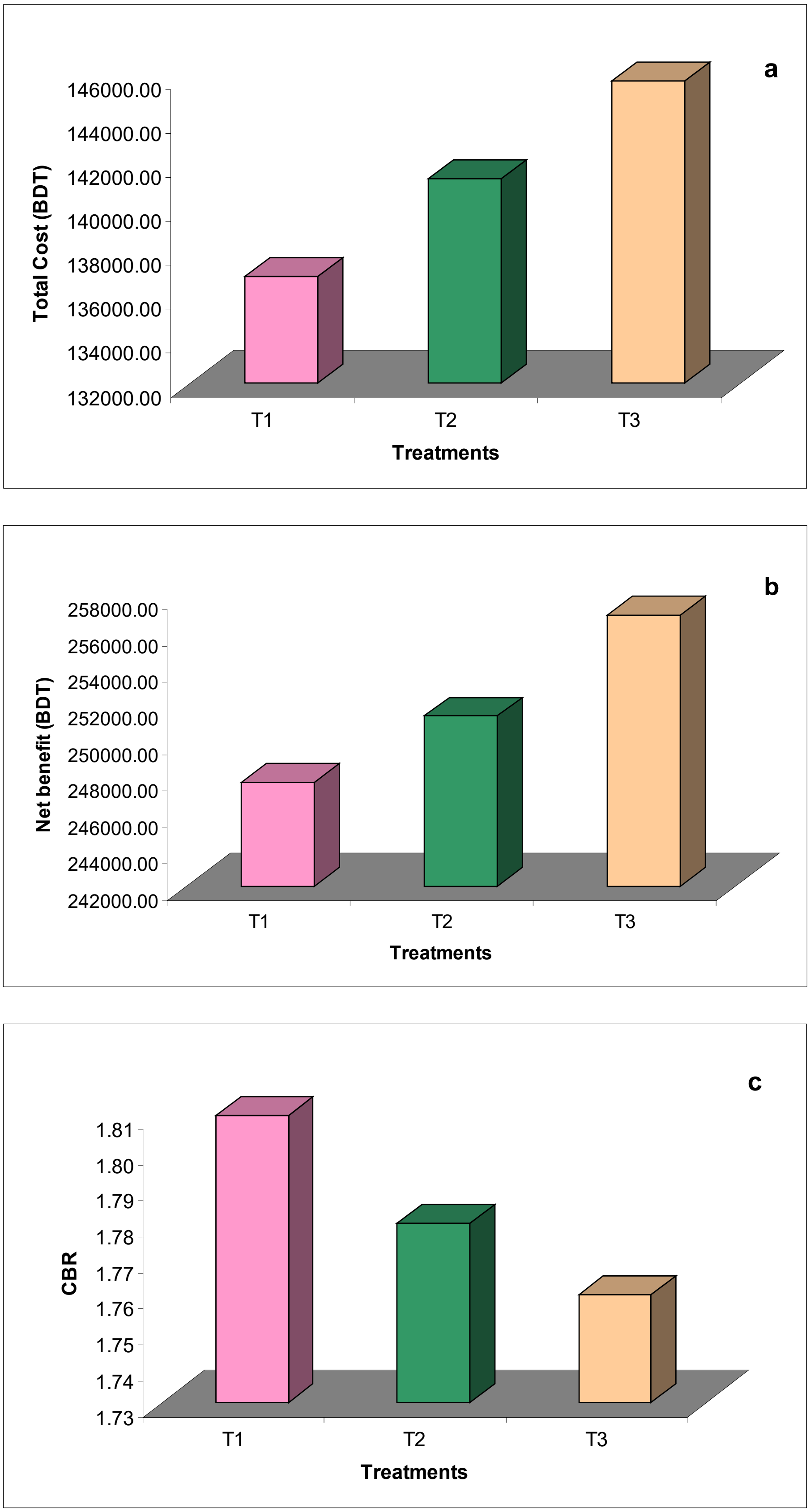


Fig. 5.5: Economics of fish farming under different treatments: a; total cost (BDT.), b; net benefit (BDT) and c; CBR

5.4: Discussion

5.4.1: Water quality parameters

Fortnightly variation

Water temperature

Water temperature varied from 30.13±0.15 (T_3 at 12th fortnight) to 33.47±0.18°C (T_3 at 6th fortnight). Lower temperature (30.13±0.15) with treatment T_3 at 12th fortnight (September 2012) might be due to start of winter season when air temperature was decreased gradually (Appendix-2). Higher water temperature (33.47±0.18°C) with treatment T_3 at 6th fortnight (June, 2012) might be due to summer season (Appendix-2). The change of water temperature might be due to the change of weather condition from summer to winter season. No significant difference was found among the treatments for the fortnightly values of temperature. Wahab *et al*. (1996) recorded water temperature as 28.5 to 31.3ºC in fish pond which was closer to the findings of the present study. The fortnightly fluctuation in water temperature appeared to be due to heavy rainfall resulting in reduced temperature condition as well as bright sunlight leading to warming up of the pond water. Vass and Sachlan (1955) stated that temperature of shallow and small pieces of water bodies might follow the air temperature.

Water transparency

In the present study, water transparency was found to range from 30.33±0.88 (T_3 at 8th fortnight) to 34.67±0.33 cm (T_1 at 2nd and 4th fortnight). The lower value of the water transparency of the treatment might be due to the direct effect of basal and monthly fertilization. The values of transparency also varied with sampling date, which could be due to differences in abundance of plankton and suspended particles. Azim *et al*. (1995) found similar water transparency (36.2 cm) in weed based system. Significant variation in transparency values was found at 2nd, 7th and 11th fortnights among the treatments, these variations might be due to rainfall and / or nutrient concentrations. Thy *et al.* (2004) reported that mean value of transparency (cm) was 30.7 in effluent plus duckweed pond. Boyd (1982) recommended a transparency between 30 to 45 cm as appropriate for fish culture.

Dissolved Oxygen (DO)

Dissolved Oxygen (DO) content is probably the only most important water quality parameters in aquaculture. The DO concentrations varied from 5.00±0.06 (T_3 at 7th and 8th fortnight) to 6.15±0.10 mg/l (T_1 at 4th fortnight). Openheimer *et al*. (1978) and Wahab *et a*l. (1995) recorded dissolved oxygen values ranged from 3.18 to 7.58 and 2.2 to 7.1 mg/l, respectively. Significant variations in DO values were found at 1st, 2nd, 3rd, 5th and 6th fortnights among the treatments. Fortnightly variations might be due to fluctuation of temperature (Appendix-2). The concentration of DO showed a decreasing trend with the progress of culture duration, obviously due to the increase in biomass with the progress of culture (Jena *et al*., 1998).

Hydrogen ion concentration (pH)

The pH in the natural water has great importance as it regulates the productivity of water body. The values of pH in the water ranged from 6.93±0.07 (T_3 at 7th fortnight) to 8.10±0.06 (T_3 at 3rd fortnight). The neutral to slightly alkaline pH in the study pond were possibly due to local soil condition and natural waters. Wurts and Durbrow (1992) stated that pH of a waterbody depends both soil and water condition. Moreover, the initial lime treatment during pond preparation possibly helped in maintaining carbon buffer system in the pond water (Khan *et al*., 2009). Ferdoushi *et al*. (2008) found the range of pH was 7.53±0.34 to 8.09±0.46 in weed based carp polyculture pond.

Total alkalinity

Total alkalinity was found to range from 106.33±1.76 (T_2 at 10th fortnight) to 123.00±1.53 mg/l (T_2 at 4th fortnight). It might be due to low dissolved oxygen content and more production of free CO_2 that enhanced by increasing of fish biomass which strongly supported by Michael (1968) while working with water quality parameters in fish ponds and tropical impoundment. Boyd (1998) stated that the acceptable range of alkalinity for freshwater fish culture is between 40 to 200 mg/l. Significant variations in alkaline values were found at 3rd, 4th, 7th, 9th and 10th fortnights among the treatments. It might be due to variation in rainfall (Appendix-2). Total alkalinity values depending upon the location, season, plankton population, nature of bottom deposits etc. (Jhingran, 1991). In the present study, the alkalinity levels in water were within the productive range as stated by Rahman *et al*. (1982).

Free carbon dioxide (CO_2)

The mean values of free carbon dioxide varied from 2.03±0.03 (T_1 at 6th fortnight) to 3.18±0.07 mg/l (T_3 at 12th fortnight). The higher value of free CO_2 content was obtained during the last month of the experiment (September, 2012) due to higher fish production. The suitable range of free CO_2 for fish culture is ranged from 1.0 to 10.0 mg/l (Boyd, 1998). Significant variation was found at 3rd, 4th, 8th and 10th fortnights among the treatments. It might be due to variation in rainfall (Appendix-2). The fluctuation in CO_2 values might be due to alteration in the rate of photosynthesis in the pond and due to rate of DO consumption by fish through respiration. Talukdar *et al*. (2012) recorded the value of free CO_2 as 2.85 mg/l while working on suitability of aquatic macrophytes as fish feed in carp polyculture system.

Mean variation

Water temperature

In the present study, the mean value of water temperature varied from 31.76±0.30 (T_3) to 31.93±0.27°C (T_1). The findings of the present study is quite similar to the findings recorded by Kabir *et al*. (2009) who worked on the duckweed fed polyculture in pond and reported the water temperature ranged between 29.50-31.65°C. Azim and Wahab (2003) found water temperature of 18.2 to 27.8°C in the duckweed fed polyculture pond. Water temperature of 25 to 32°C is considered suitable for fish culture (Boyd and Zimmermann, 2000). In another study, Effiong *et al*. (2009) found water temperature as 27.72±0.01°C in weed based system.

Water transparency

The mean value of water transparency in this study varied from 32.25±0.34 (T_2) to 33.11±0.33 cm (T_1). Azim and Wahab (2003) reported Secchi disc reading as 9.0– 42.0 cm in duck weed fed polyculture pond. Chowdhury *et al*. (2008) found the transparency value ranged from 28.66 to 34.50 cm in pond where duckweed was used as supplementary feed. Boyd (1982) recommended a transparency between 30 to 45 cm as appropriate for fish culture. Wahab *et al*. (1994) found transparency depth ranging from 15.0 to 74.0 cm in polyculture ponds. Rahman (1992) concluded that the transparency of productive water bodies should be 40.00 cm or less.

Dissolved Oxygen (DO)

The mean value of dissolved oxygen varied from 5.32±0.09 (T_3) to 5.41±0.09 mg/l (T_1). The higher value of dissolved oxygen was found in T_1 due to comparatively lower stocking density. Talukdar *et al*. (2012) recorded mean value of DO ranging from 6.23 mg/l to 6.63 mg/l while working on suitability of duckweed as feed for fish in polyculture system. Fluctuation of dissolved oxygen concentration might be attributed to photosynthetic activity and variation in the rate of oxygen consumption by fish and other aquatic organisms (Boyd, 1982). The suitable range of dissolved oxygen is 5-8 mg/l for fish culture (Boyd, 1998).

Hydrogen ion concentration (pH)

The mean values of pH varied from 7.25±0.07 (T_2) to 7.35±0.09 (T_1). Slight alkaline condition (7.35) was good for fish culture. The range of pH obtained in the resent study is suitable for fish culture which is agreed with Boyd (1998). Swingle (1967) considered pH values of 6.5 to 9.0 as satisfactory level for fish culture. The findings of the present study also agree well with the observation of Talukdar *et al*. (2012) who recorded the pH value as 7.45±0.21 while working on suitability of duckweed as fish feed in polyculture system. Majhi *et al.* (2006) reported pH 7.5 – 8.2 in two ponds were fed with organically produced Azolla.

Total alkalinity

The recorded mean total alkalinity varied from 110.81±0.85 (T_3) to 112.56±0.94 mg/l (T_1). It is desirable to have an alkalinity of above 20 mg/l for optimal fish production (BAFRU, 1990). Alkalinity has direct effect on primary productivity. In low alkalinity aquatic environments certain nutrients are unavailable to aquatic life (Wurts and Durbrow, 1992). Mairs (1996) considered a total alkalinity of 40.0 mg/l or more to be productive than water bodies with lower alkalinity. Ferdoushi *et al*. (2008) recorded total alkalinity as 133.87±18.95 mg/l in Azolla fed fish pond. In another study, Kabir *et al*. (2009) recorded alkalinity value ranged from 61 to 97.5 mg/l in duckweed fed polyculture pond.

Free Carbon-dioxide (CO_2)

Results from the study indicated that the value of CO_2 varied from 2.64±0.07 (T_1) to 2.87±0.08 mg/l (T_3) was not harmful for fish culture. This assumption was supported by Boyd (1998). According to Moriarty (1997), biochemical pathway of organic matter decomposition requires oxygen. Carbon-dioxide is produced by this process makes the water more acidic, which resulted in lower pH and lower alkalinity value. Higher photosynthesis might be resulted in higher DO and lower free CO_2 concentration in the water column. Talukdar *et al*. (2012) in their study on suitability of duckweed as fish feed recorded free CO_2 value of 2.85±0.30 mg/l which was also strongly agreed with the findings of the present study.

5.4.2: Growth of fishes

5.4.2.1: Monthly variations

Specific growth rate (SGR, %, bwd^{-1})

The specific growth rate (%, bwd^{-1}) varied with *H. molitrix* from 0.53±0.01 (T_2 at 6^{th} month) to 2.68±0.02 (T_1 at 1^{st} month), *C. catla* from 0.48±0.003 (T_3 at 6^{th} month) to 2.63±0.003 (T_1 at 1^{st} month), *L. rohita* from 0.39±0.01 (T_2 at 6^{th} month) to 2.04±0.07 (T_1 at 1^{st} month), *C. cirrhosus* from 0.39±0.02 (T_2 at 6^{th} month) to 2.30±0.11 (T_2 at 1^{st} month), *C. carpio* from 0.50±0.03 (T_3 at 6^{th} month) to 2.28±0.16 (T_1 at 1^{st} month), *C. idella* from 0.49±0.01 (T_2 at 6^{th} month) to 2.98±0.04 (T_1 at 1st month) and *B. gonionotus* from 0.46±0.02 (T_3 at 6th month) to 3.42±0.07 (T_1 at 1st month) . Among the species, the highest SGR was observed in *B. gonionotus* as 3.42±0.07 %, bwd^{-1} and the lowest was in *L. rohita* as 0.39±0.01 %, bwd^{-1}. *B. gonionotus* showed highest SGR, possibly due to the availability of macrophytes. Talukdar *et al*. (2012) reported the highest SGR for *B. gonionotus* among the carp species in duckweed fed ponds. Lowest SGR in *L. rohita* might be due to the fact that indigenous rohu (*Labeo rohita*) is not affected by duckweed (Azim and Wahab, 2003). Grass carp showed moderately higher SGR, possibly due to the availability of macrophytes (Roy *et al*. 2002).

The lowest combined SGR value was found as 0.47±0.022 (T_2 at 6th month) and the highest combined SGR was found as 2.60±0.18 (T_1 at 1st month). The highest SGR value was found in the month of April and the lowest value was found in the month of September for all the species. The lowest SGR value in the month of September might be due to the slow growth rate at the starting of winter season. Slow growth due to slow metabolic activity of fish is found in lower water temperature (Boyd, 1998).

Monthly weight gain (g/month)

The weight gain (g/month) varied with *H. molitrix* from 66.33±0.88 g (T_3 at 1st month) to 84.00±1.53 g (T_1 at 4th month), *C. catla* from 68.33±0.88g (T_3 at 1st month) to 94.33±1.76 g (T_1 at 3rd month), *L. rohita* from 38.67±1.33 g (T_3 at 5th month) to 59.67±0.88 g (T_1 at 4th month), *C. cirrhosus* from 42.67±2.33 g (T_3 at 5th month) to 73.33±2.40 g (T_1 at 4th month), *C. carpio* from 51.00±2.08 (T_2 at 1st month) to 91.67±3.28 g (T_1 at 3rd month), *C. idella* from 89.00±3.21 (T_3 at 5th month) to 115.67±1.76 g (T_1 at 3rd month) and *B. gonionotus* from 32.33±1.33 (T_3 at 6th month) to 53.33±0.33 g (T_1 at 4th month). Among the species, the highest monthly weight gain was observed in *C. idella* as 115.67±1.76 g due to herbivorous nature and the lowest was in *B. gonionotus* as 32.33±1.33 g which might be due to slow growth pattern. Azad *et al*. (2004) reported the weight gain for *H. molitrix* as 91.78 and *C. cirrhosus* as 85.75g in carp polyculture system which were more or less closer to the present findings.

The lowest combined weight gain value was found as 56.81±7.29 (T_3 at 1st month) and the highest combined weight was found as 80.62±7.64 (T_1 at 4th month). The highest weight gain was found in the month of July and the lowest value was found in the month of April for all the species. Most of the species gains highest weight gain in 3rd or 4th month which might be due to the favourable temperature during this study (Appendix-2). The low growth rate of fishes in treatment T_3 appeared to be related with higher densities and increased competition for food and space (Haque *et al*., 1994; Islam, 2002).

Mean variations

Specific growth rate (%bwd^{-1})

The mean specific growth rate varied with *H. molitrix* from 1.16±0.30 (T_3) to 1.23±0.32 (T_1), *C. catla* from 1.16±0.29 g (T_3) to 1.21±0.32 (T_1), *L. rohita* from 0.96±0.21 (T_3) to 1.01±0.25 (T_1), *C. cirrhosus* from 0.98±0.23 (T_3) to 1.10±0.26 (T_1), *C. carpio* from 1.14±0.25 (T_3) to 1.21±0.28 (T_1), *C. idella* from 1.21±0.34 (T_3) to 1.28±0.38 (T_1) and *B. gonionotus* from 1.35±0.39 (T_3) to 1.43±0.44 (T_1). Kabir *et al*. (2009) reported the SGR value of *H. molitrix*, *C. cirrhosus*, *B. gonionotus* and *C. carpio* as 1.38, 1.25, 1.24 and 1.34%, respectively in duckweed fed fish culture ponds.

Specific growth rate of exotic carps, viz., grass carp, silver carp, common carp and Thai sharpunti showed higher values than those of Indian major carps, viz., catla, rohu and mrigal. It is due to the fact that silver carp (*H. molitrix*) is recognized for its rapid growth rate, common carp (*C. carpio*) shows better growth rte over mrigal (*C. cirrhosus*) and Thai punti (*B. gonionotus*) is primarily macrophyte feeder (Morrice, 1998). Further, among the exotic species, *B. gonionotus* showed the highest specific growth rate (1.35±0.39–1.43±0.44%) than those of the other two, attributed to its inherent higher growth potential and taking Azolla as feed. Higher growth rates of all the exotic species over Indian major carps in the present study are in agreement with the observations by earlier workers (Lakshmanan *et al*., 1971; Chaudhuri *et al*., 1974, 1975, 1978; Sinha and Gupta, 1975; Mahaboob and Sheri, 1997; Tripathi *et al*., 2000).

Combined specific growth rate (SGR, %bwd^{-1}) of all fishes was significantly highest in treatment T_1 where the stocking density was lowest as compared to those of treatments T_2 and T_3 although the same food (Azolla) was supplied in all the treatments. Low growth rate of fishes in treatments T_2 and T_3 appeared to be related with higher densities and increased competition for food and space. A similar experience with regard to growth, i.e. retardation of fish growth at higher densities, was observed by Lakshmanan *et al*. (1971) and Jena *et al*. (1998) while working with carps and other fish species. Better growth in lower density than higher density also noted by Papoutsoqlou *et al*. (1987).

Weight gain (g/month)

The mean weight gain (g) varied with *H. molitrix* from 71.33±1.18 g (T_3) to 80.83±1.55 g (T_1), *C. catla* from 76.00±3.62 g (T_3) to 84.72±2.78g (T_1), *L. rohita* from 45.22±2.73 g (T_3) to 50.22±2.89g (T_1), *C. cirrhosus* from 46.78±1.96 g (T_3) to 60.72±3.49 g (T_1), *C. carpio* from 68.56±3.71 g (T_3) to 79.61±4.65 g (T_1), *C. idella* from 91.61±1.09 g (T_3) to 105.28±2.88 g (T_1) and *B. gonionotus* from 38.28±2.75 g (T_3) to 44.06±2.64 g (T_1). Talukdar *et al*. (2012) found similar weight gain in duckweed fed fish culture ponds as 65.86 g (*C. cirrhosus*) and 35.34 g (*B. gonionotus*). The individual weight gain of all the species were found lower in ponds with high stocking density (T_3), which might be due to high competition for feed and space that retard the weight gain.

Among the three Indian major carp species catla showed higher weight gain over, mrigal and rohu in all the treatments, which might be due to the fast growth rate of catla (*C. catla*) over mrigal (*C. cirrhosus*) and rohu (*L. rohita*). Morrice (1998) observed similar trend in weight gain for catla. Among the exotic species the highest weight gain was observed as 105.28±2.88 g in *C. idella* and the lowest was in *B. gonionotus* as 38.28±2.75 g.

The combined mean weight gain (g) of all the species were found to be higher in treatment T_1 over T_2 and T_3, due to low biomass contained at lower stocking densities of T_1 and other associated favourable environmental parameters compared to the treatments with higher densities. A similar experience with regard to growth, i.e. retardation of fish growth at higher densities, was observed by Jhingran (1991) while working with carps and other fish species.

Final Weight (g)

The final weight (g) after 6 months growing period with *H. molitrix* varied from 468.00±24.01 (T_3) to 545.00±9.61 g (T_1), *C. catla* from 521.00±6.25 (T_3) to 573.33±3.71 g (T_1), *L. rohita* from 329.33±3.71 (T_3) to 359.33±3.18 g (T_1), *C. cirrhosus* from 338.67±10.17 (T_3) to 422.33±11.61 g (T_1), *C carpio* from 472.33±3.71 (T_3) to 538.67±3.84 g (T_1), *C. idella* from 619.67±16.48 (T_3) to 701.67±7.22 g (T_1) and *B. gonionotus* from 251.33±4.06 (T_3) to 287.67±1.67 g (T_1). Kabir *et al*. (2009) worked on use of duckweed as feed for fishes in polyculture system and found final weight of *H. molitrix*, *C. cirrhosus*, *B. gonionotus* and *C. carpio* as 300, 210, 162.50 and 211.20 g/6 months, respectively which were lower than the present findings, due to stocking small sized fingerlings and shorter culture period. *C carpio* grows better than *C. cirrhosus.* Wahab *et al.* (2002) observed that common carp (*C. carpio*) grows better than its counter-part native species mrigal and does not exert significant antagonistic impact on other native carp species in polyculture.

Among the species the highest final weight was observed in as 701.67±7.22 g (T_1) in *C. idella* and the lowest was in *B. gonionotus* as 251.33±4.06 (T_3). Azolla is preferred by grass carp because of its low content of fibre and fat (Mandal *et al*. (2010). Talukdar *et al*. (2012), Morrice (1998) and Jena *et al*. (2002b) reported the highest final weight of grass carp (*C. idella*) among carp species, fed with duckweed. Jena *et al*. (1998) mentioned that Thai punti (*B. gonionotus*) is a medium sized carp species and reported to have moderate growth rate compared to the major carps. Chaudhuri *et al*. (1974, 1975), Sinha *et al*. (1973) and Sinha and Saha (1980) recorded similar higher growth rates of grass carp over other species.

The lowest mean final weight was found as 2167.67±17.31 g (T_3) and the highest final weight as 3629.34±19.52 g (T_1) for all the species. This might be due to direct impact of stocking density. Similar argument is supported by Jena *et al*. (1998) while working with the culture of Indian major carps under different stocking density.

Survival rate (%)

The mean survival rate with *H. molitrix* varied from 85.33±1.17 (T_3) to 90.33±2.91% (T_1), *C. catla* from 80.87±0.58 (T_3) to 83.63±0.75% (T_1), *L. rohita* from 83.10±2.18 (T_1) to 84.13±1.21% (T_2), *C. cirrhosus* from 85.50±0.58 (T_2) to 91.53±1.13% (T_1), *C. carpio* from 93.07±0.81% (T_2) to 94.53±0.61% (T_1), *C. idella* from 85.07±0.96 (T_2) to 86.37±0.52% (T_1) and *B. gonionotus* from 80.50±1.15 (T_1) to 81.73±0.79% (T_3). Talukdar *et al*. (2012) found survival rate as 82% (*C. catla*), 88% (*B. gonionotus*) in the weed based carp polyculture system. In a yearlong grow-out carp polyculture trial with olive barb as a component species at different species combinations and ratios, Chakraborty *et al*. (2005) in Bangladesh observed 75.5–78.6% survival in silver carp and catla, 73.2–82.4% in rohu and 65.2–75.4% in mrigal. Similar survival rate of silver carp followed by rohu, mrigal and catla have also been reported earlier in some grow-out carp polyculture trials (Tripathi *et al*., 2000; Jena *et al*., 2002a). In contrast, we recorded higher survivals in all the species, attributed to the relatively larger stocking size and lower stocking density (except *B. gonionotus*). The lowest mean survival rate was found as 85.20±1.55 % (T_3) and the highest survival rate as 87.14±1.94 % (T_1) for all the species .Variation in stocking density of fish may change growth and survival rates (Miao, 1992).

Yield (Kg/ha/6 months)

The yield (Kg/ha/6 months) with *H. molitrix* varied from 969.00±17.16 (T_1) to 982.67±50.35 (T_3), *C. catla* from 241.00±1.53 (T_1) to 411.67±4.81 (T_3), *L. rohita* from 603.67±5.21 (T_1) to 781.00±8.62 (T_3), *C. cirrhosus* from 375.67±10.17 (T_1) to 426.33±12.84 (T_3), *C. carpio* from 252.67±1.86 (T_1) to 419.67±3.38 (T_3), *C. idella* from 520.33±13.87 (T_3) to 884.00±9.07 (T_1) and *B. goninotus* from 496.67±8.11 (T_3) to 568.33±3.33 (T_1). Azad *et al*. (2004) reported that Azolla for *C. idella* show encouraging result.

In treatment T_1, grass carp (*C. idella*) contributed 22.70% of total fish production and Thai punti (*B. gonionotus*) contributed 14.59% of total fish production. In treatment T_2, grass carp (*C. idella*) contributed 17.30% of total fish production and Thai punti (*B. gonionotus*) contributed 13.34% of total fish production. In treatment T_3, grass carp (*C. idella*) contributed 12.88% of total fish production and Thai punti (*B. gonionotus*) contributed 12.30% of total fish production. Macrophytophagus species (*C. idella* and *B. gonionotus*) contributed 37.29%, 30.64% and 25.18% in treatment T_1, T_2 and T_3, respectively. In addition, it is assumed that the uneaten dead Azolla along with fish faeces settled on to the bottom and consumed directly by common carp and supplied nutrients for phytoplankton.

The highest combined yield (4038.33±84.41 kg/ha/6 months) was obtained from treatment T_3 stocked with high density of fish. The increased growth and production with higher density of fish might have been due to the proper stocking density, synergistic interaction and confounding effects of additional numbers of silver, rui, catla, mrigal and carpio. Significant difference was found among the treatments. The net production of this experiment is comparable to other reported productions in semi-intensive polyculture in Bangladesh. Gopakumar *et al.* (1999) mentioned that the production of weed based carp polyculture was 3-4 tonnes/ha/year which was lower than the production of the present study. It might be due to the good water quality and regular supply of Azolla. Grover *et al*. (2000) mentioned that the possible production of Azolla based carp polyculture was 5575 kg/ha which was more or less closer to the findings of the present study. Jena *et al*. (2002b) also reported the total production as 3472 kg/ha in 6 months in carp polyculture system.

Mazid *et al*. (1997) recorded gross fish production of 2545–3688 kg/ ha during 330-day culture period, the highest production with artificial feed using 53% rice bran, 30% mustard oil cake, 10% fish meal and 6% molasses and the lowest with the traditional 75% rice bran and 25% mustard oil cake. Kohinoor *et al*. (1999) reported a gross fish production of 2056 kg/ha in ponds supplied with only duckweed and 2566 kg/ha in ponds supplied with only rice bran during a 180-day culture period.

5.4.3: Economics

Along with the increase in production, the purpose of aquaculture practices is to earn a profit. Wyban *et al.* (1988) indicated that stocking density, growth rate, survival and market price are the most sensitive factors to increase profit. Total investment cost and total return were directly related to stocking density. The highest density required the highest total investment cost and also provides the highest return.

During study period total cost, gross benefit, net benefit and CBR varied from 136862.00±606.45 Tk/ha/6 months (T_1) to 145754.00±57.35 Tk/ha/6 months (T_3), 384562.35±1890.32 (T_1) to 402667.35±8862.88 Tk/ha/6 months (T_3), 247700.35±1890.32 (T_1) to 256913.35±8862.88 Tk/ha/6 months (T_3) and 1.76±0.06 (T_3) to 1.81±0.02 (T_1), respectively.

Total cost was higher in Treatment T_3 might be due to the higher stocking density i.e. seed cost (24.54% of total cost). Roy *et al*. (2003) studied economics of carp-SIS polyculture and their economic analysis under 3 treatments and they mentioned the operational cost was 32,450.00, 39,950.00 and 42,450.00 Tk./ha/7 months in treatments T_1, T_2 and T_3, respectively which was lower than the present study might due to comparatively smaller size of stocked fish seed. In another Grover *et al*. (2000) described total cost as 85,000.00 BDT/ha which more or less similar to the present study. Gross benefit was varied from 384562.35±1890.32 BDT/ha (T_1) to 402667.35±8862.88 BDT/ha (T_3) which were higher than the findings of Roy *et al*. (2003) who reported the gross benefit was 128,000.00, 128,280.00 and 110,720.00 Tk./ha/7 months in treatments T_1, T_2, and T_3, respectively because of lower production rate than the present study. In case of net benefit, Majhi *et al*. (2006) reported the net benefit of 227338.00 BDT/ha was obtained from Azolla fed pond which was slightly lower than the present findings. Shanmugasundaram and Balusamy (1993) stated that benefit cost ratio was 1.88 which was similar to the present study. Khan *et al*. (2009) also mentioned BCR value of 1.22 which was lower than the findings of the present study was due to high initial biomass of all the species and also the higher survival rate.

Inspite of having lowest total fish production with treatment T_1 best growth performance of macrophytophagus species was found with that treatment. This indicated that treatment T_1 was found most potential for the development of low cost fish farming which was reflected with having significantly lowest total cost and highest CBR with that treatment. The study indicated that Azolla based carp polyculture with stocking density of 9880 fish/ha could be used for low cost weed based fish farming in Bangladesh.

5.5: Conclusion

Considering the water quality, production and economics, it can be concluded that Azolla based carp polyculture with stocking density of 9880 fish/ha be used for low cost Azolla based fish farming in Bangladesh.

5.6: Recommendation

In this study Azolla based carp polyculture with stocking density of 9880 fish/ha was found more profitable. Potentials of Azolla for farming of macrophytophagus fishes other than carps were not included in this study. Studies on Azolla based farming for macrophytophagus fishes other than carps are recommended as future step.

CHAPTER SIX

Summary, Conclusion and Recommendation

Weed based aquaculture has been demonstrated to be one of the easiest method of fish production requiring less capital which improves sustainability, productivity and profitability. The aim of the present study was to explore the potentials of weed based aquaculture as a low cost technology in ponds. A total of 3 experiments were conducted in 3 separate years (2010, 2011 and 2012). Experiment-1 was conducted at the Protein and Enzyme Research Laboratory, Department of Biochemistry and Molecular Biology, Rajshahi University, Rajshahi whereas experiment-2 and experiment-3 were conducted at Alampur village of Sadar Upazila under Kushtia district, Bangladesh. In experiment-1, six different types of conventional and non-conventional fish feed items like rice bran, wheat bran, mustard oilcake, Azolla, grass and banana leaves were tested to determine the nutrient contents (protein, lipid and carbohydrate) under 6 treatments as T_1, T_2, T_3, T_4, T_5 and T_6, respectively. Considering the nutrient content in experiment-1, experiment-2 evaluated the fish production and economics under 4 treatments of feed and weed based system with a similar stocking density of 11115 fish/ha in polyculture ponds as T_0: ponds fed with conventional feed like rice bran, wheat bran and mustard oilcake (no weed was used as fish feed), T_1: Azolla (*Azolla pinnata*) fed ponds, T_2: Grass (*Cynodon dactylon*) fed ponds and T_3: Banana (*Musa acuminata*) leaf fed ponds. Based on the performance of weeds and feeds in experiment-2, experiment-3 optimized the stocking density for Azolla based carp polyculture system in ponds under 3 different treatments of stocking densities like T_1: 9880 fish/ha, T_2: 11115 fish/ha and T_3: 12350 fish/ha.

Nutrients in weeds and feeds were compared for a period of 6 months (April to September) in experiment-1. Fishes (*Hypophthalmichthyes molitrix, Catla catla, Labeo rohita, Cirrhinus cirrhosus, Cyprinus carpio, Ctenopharyngodon idella* and *Barbonymus gonionotus*) were also grown for a period of 6 months (April to September) in experiment-2 and experiment-3. Mean initial stocking weight of *H. molitrix*, *C. catla*, *L. rohita*, *C. cirrhosus*, *C. carpio*, *C. idella* and *B. gonionotus* were 62, 64, 57, 54, 63, 65 and 25 g, respectively for experiment-2 and 60, 65, 58, 52, 61, 70 and 22 g, respectively for experiment-3. There were 3 replications for each treatment under different experiments.

Liming (250 kg/ha) and basal fertilization (cowdung: 1500 kg/ha, urea: 60 kg/ha and TSP: 60 kg/ha) were done for all the treatments under experiment-2 and experiment-3. Urea (2.5 kg/ha/day in all treatments except T_1 under experiment-2 and in no treatment under experiment-3) and TSP (2.5 kg/ha/day in all treatments under experiment-2 and experiment-3) were applied as periodic fertilization.

In case of experiment-1, nutrient contents (protein, lipid and carbohydrate) were monitored monthly whereas in case of experiment-2 and experiment-3 water quality parameters (water temperature, transparency, DO, pH, alkalinity and free CO_2) were monitored fortnightly and fish growth parameters (weight gain and SGR) were monitored monthly. Economics (in terms of total cost, gross benefit, net profit margin and CBR) of fish farming were also evaluated for both the experiment-2 and experiment-3.

In experiment-1, significant variations were found in the mean values of nutrient contents with different treatments of feed items but in case of same feed item no significant difference was found in the nutrient content at different months. Among the non-conventional feed items treatment T_4 (Azolla) varied more significantly for the mean values of protein content.

In experiment-2, the mean values of water temperature, transparency, DO, pH, total alkalinity and free CO_2 varied from 31.19±0.20 (T_3) to 31.29±0.24°C (T_0), 32.28±0.32 (T_2) to 32.83±0.40 cm (T_1), 5.33±0.09 (T_3) to 5.51±0.11 (T_1) mg/l, 7.18±0.03 (T_3) to 7.38±0.05 (T_1), 113.28±0.85 (T_1) to 114.36±0.72 (T_0) mg/l, and 2.82±0.07 (T_1) to 3.03±0.07 (T_0), respectively. Considering all species, mean values of SGR (%, bwd^{-1}), monthly weight gain (g), final weight (g), survival rate (%) and yield (Kg/ha/6 months) of fishes significantly varied from 0.93±0.03 (T_3) to 1.17±0.05 (T_0), 42.33±6.71 (T_3) to 76.64±9.24 (T_0), 2167.67±17.31 (T_3) to 3629.34±19.52 (T_0), 76.33±1.74 (T_2) to 79.52±2.20 (T_0) and 2541.00±0.67 (T_3) to 4403.51±0.88 (T_0), respectively. Total cost (BDT/ha), gross benefit (BDT/ha), net benefit (BDT/ha), net profit margin (%) and CBR significantly varied from 123430.50±0.00 (T_1, T_2, T_3) to 235930.50±0.00 (T_0), 235068.40±1965.31 (T_3) to 418376.85±5125.59 (T_0). 111639.90±2056.87 (T_3) to 206744.85±3221.73 (T_1), 77.21±2.40 (T_0) to 167.20±18.77 (T_1) and 0.77±0.02 (T_0) to 1.67±0.18 (T_1), respectively. Findings indicated that treatment T_1 (Azolla based carp polyculture) was more profitable than that of other treatments.

In experiment-3, the mean values of water temperature, transparency, DO, pH, total alkalinity and free CO_2 varied from 31.76±0.30 (T_3) to 31.93±0.27°C (T_1), 32.25±0.34 (T_2) to 33.11±0.33 cm (T_1), 5.32±0.09 (T_3) to 5.41±0.09 mg/l (T_1), 7.25±0.07 (T_2) to 7.35±0.09 (T_1), 110.81±0.85 (T_3) to 112.56±0.94 mg/l (T_1), and 2.64±0.07 (T_1) to 2.87±0.08 mg/l (T_3), respectively. Considering all species, mean SGR (%, bwd^{-1}), monthly weight gain (g), final weight (g), survival rate (%) and yield (Kg/ha/6 months) of fishes significantly varied from 1.14±0.05 (T_3) to 1.21±0.05 (T_1), 62.54±7.36 (T_3) to 72.21±8.15 (T_1), 3000.33±31.25 (T_3) to 3428.00±25.35 (T_1), 85.20±1.55 (T_3) to 87.14±1.94 (T_1) and 3894.33±18.00 (T_1) to 4038.33±84.41 (T_3), respectively. Total cost (BDT/ha), gross benefit (BDT/ha), net benefit (BDT/ha), net profit margin (%) and CBR significantly varied from 136862.00±606.45 (T_1) to 145754.00±57.35 (T_3), 384562.35±1890.32 (T_1) to 402667±8862.88 (T_3), 247700.35±1890.32 (T_1) to 256913.35±8862.88 (T_3), 176.31±5.55 (T_3) to 181.00±1.53 (T_1) and 1.76±0.06 (T_3) to 1.81±0.02 (T_1), respectively. Inspite of having lowest total fish production with treatment T_1 best growth performance of macrophytophagus species was found with that treatment. This indicated that treatment T_1 was found most potential for the development of low cost fish farming which was reflected with having significantly lowest total cost and highest CBR with that treatment. The study indicated that Azolla based carp polyculture with stocking density of 9880 fish/ha could be used for low cost weed based fish farming in Bangladesh.

In this study Azolla based carp polyculture with a stocking density of 9880 fish/ha was found more profitable. Potentials of Azolla for farming of macrophytophagus fishes other than carps were not included in this study. Studies on Azolla based farming for macrophytophagus fishes other than carps are recommended as future step.

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APPENDICES

Appendix-1: Meteorological data of Kushtia district in the year of 2010

Parameters \ Months	April	May	June	July	August	September
Air temperature (°C)	32.82	32.95	34.02	32.50	32.00	31.52
Average Rainfall (mm)	84.00	171.00	351.00	330.00	418.00	235.00

Source: Bangladesh Meteorological Department, First class Meteorological Observatory, Chuadanga, Bangladesh

Appendix-2: Meteorological data of Kushtia district in the year of 2011

Parameters \ Months	April	May	June	July	August	September
Air temperature (°C)	32.65	33.25	34.15	33.26	32.64	30.25
Average Rainfall (mm)	85.00	150.00	358.00	321.00	403.00	239.00

Source: Bangladesh Meteorological Department, First class Meteorological Observatory, Chuadanga, Bangladesh

Appendix-3: Meteorological data of Kushtia district in the year of 2012

Parameters \ Months	April	May	June	July	August	September
Air temperature (°C)	33.25	33.80	34.25	33.80	32.20	31.65
Average Rainfall (mm)	88.00	166.00	384.00	352.00	415.00	243.00

Source: Bangladesh Meteorological Department, First class Meteorological Observatory, Chuadanga, Bangladesh