GROWTH PERFORMANCE OF *Oreochromis niloticus* (Linnaeus, 1758), *Cyprinus carpio* (Linnaeus, 1758) AND *Tor pitutora* (F. Hamilton, 1822) IN RECIRCULATING AQUACULTURE SYSTEM

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RECOMMENDATIONS

This is to recommend that the thesis entitled **"GROWTH PERFORMANCE OF *Oreochromis niloticus* (Linnaeus, 1758), *Cyprinus carpio* (Linnaeus, 1758) *and Tor pitutora* (F. Hamilton, 1822) IN RECIRCULATING AQUACULTURE SYSTEM"** has been carried out by Genuine Prajapati for the partial fulfillment of Master's Degree of Science in Zoology with special paper Fish Biology and Aquaculture. This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

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LETTER OF APPROVAL

On the recommendation of supervisor "Ms. Santoshi Shrestha" this thesis submitted by Genuine Prajapati entitled **"GROWTH PERFORMANCE OF *Oreochromis niloticus* (Linnaeus, 1758), *Cyprinus carpio* (Linnaeus, 1758) *and Tor pitutora* (F. Hamilton, 1822) IN RECIRCULATING AQUACULTURE SYSTEM"** is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Fish Biology and Aquaculture.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Genuine Prajapati entitled **"GROWTH PERFORMANCE OF *Oreochromis niloticus* (Linnaeus, 1758), *Cyprinus carpio* (Linnaeus, 1758) *and Tor pitutora* (F. Hamilton, 1822) IN RECIRCULATING AQUACULTURE SYSTEM"** has been accepted as partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Fish Biology and Aquaculture.

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DECLARATION

I hereby declare that the work presented in this thesis has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

Date: 2078/11/15

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ABSTRACT

This study presents the introduction of Recirculating Aquaculture System (RAS) in Nepal and experimentation on comparison of growth performance of three different species of fish commonly found in Nepal. With the limited study on RAS in Nepal, this study aims in providing and uplifting agricultural technologies. The three studied species are Nile Tilapia, Common Carp and Golden Mahseer. All three species were grown in grow tanks T1, T2 and T3 respectively with three simultaneous replications. Each tanks were 1.5m in diameter and 1.2m in height at the circumference and 1.5m at the central. The tanks were made up of composite Fiber Reinforced Plastic (FRP) for durability and longevity. In each tanks, 200 fingerlings were introduced. Maintaining the similar optimum water parameters, the experiment was performed. Fishes were reared for six months feeding 35% crude protein locally available feed. Common Carp showed highest growth performance with mean weight gain of 1234.63±9.1g and specific growth rate of 2.53. on the other hand, Golden Mahseer showed the lowest growth performance of 45.29±0.7g and specific growth rate of 3.4. It depicts that Common Carp is more suitable fish for RAS than Tilapia and Mahseer.

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LIST OF ABBREVIATIONS

RAS	:	Recirculating Aquaculture System
CP	:	Crude Protein
PPM	:	Parts Per Million
FRP	:	Fiberglass Reinforced Plastics
TSS	:	Total Dissolved Solids
TAN	:	Total Ammonia Nitrogen
FAO	:	Food and Agriculture Organization
IUCN	:	International Union for Conservation of Nature
DO	:	Dissolved Oxygen
BOD	:	Biological Oxygen Demand
UV	:	Ultra Violet
CAARP	:	Center for Aquaculture-Agriculture Research and Production
WG	:	Weight gain
LG	:	Length Gain
ADG	:	Average daily weight gain
ADL	:	Average daily length gain
FCR	:	Feed Conversion Ratio
SGR	:	Specific Growth Rate
SR	:	Survival Rate

CHAPTER-ONE

1. INTRODUCTION

Recirculating Aquaculture System (RAS) have evolved over the past fifty years through research and development. To date, with the advancement in research and technologies, RAS have been spread throughout the globe.

Recirculating Aquaculture System is a technology where water is recycled and reused after mechanical and biological filtration and removal of suspended matter and metabolites for the culture of fish. This method is optimum for high- density fish farming with minimum land area and water. It is a form of intensive way of high-density fish culture unlike other aquaculture production systems.

The possibility thanks to these systems to handle, store and treat waste products accumulated during the growth of farmed fish represent a key factor for the development of environmentally friendly management of aquaculture production systems (Piedrahita, 2003; van Rijn, 1996). They adopt a closed farming system (or recycled) that allows the reuse of farm water thanks to a series of filtrations, thus limiting not only the removal - 10 - from natural water resources, but also the impact on the environment reducing the volume of waste generated treated in the same system (Buono, 2005; Lahav et al., 2009).

These systems offer several advantages compared to traditional technologies: the possibility to be placed near the fish markets, high product quality, shorter production cycles due to high food conversion factors and a constant monitoring of the farm environment in order to improve rearing conditions (Singh et al., 1999). However, one of the biggest problems that recirculating aquaculture companies meet is linked to the high initial investment required for the design and construction of plants; it is also recovered relatively quickly thanks to the high productions obtained (Buono, 2005).

The traditional practice of fish farming includes fish culture in open ponds and raceways with semi-intensive and extensive ways of farming practices. RAS on the other hand, is commonly indoor and intensive practice.

The system requires the removal of particulates as a part of filtration process to introduce the water back to the fish tanks. With the inclusion of suspended particles, the particulates cannot be removed only by sedimentation process. Therefore, “drum filter” or “sand filter” are used to remove the solid particulates including suspended and dissolved solutes through the process called mechanical filtration.

Mechanical filtration removes the solid wastes from the system including suspended solid particles, fecal matter, feed remnants and undigested feeds. Drum filter is the most widely used equipment for mechanical filtration as it is more efficient in solids removal. The size of the drum filter varies with the size of the system and stocking density.

The visible solid particles are not only the wastes required to be removed. As the fish fecal matter constitute of majority of ammonia, it is required to be flushed out of the system through filtration. For this process, biological filtration is used. Biofilter is a key component of RAS which is the house to nitrifying bacteria that convert harmful ammonia to nitrite and nitrate which is the least toxic form of nitrogen.

Also, a RAS can be made more efficient by adding accessory components to the system as: unit for the administration of ozone, for the wastewater disinfection and organic waste removal; degassing unit, for carbon dioxide removing; monitoring and control systems (Michaud, 2007)

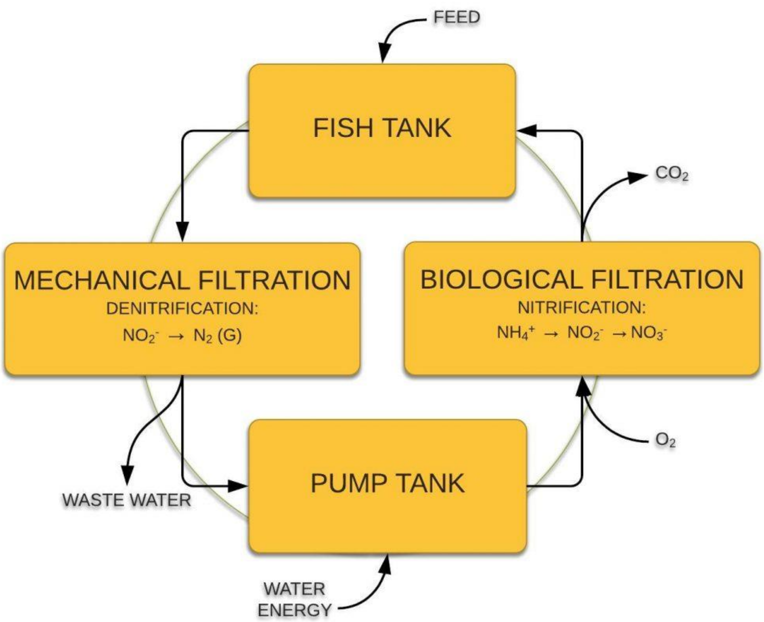

Figure 1: Recirculating Aquaculture System diagram (Source: Aquaculture ID)

Nepal, the home to abundant fresh water resources, has been established as an agricultural country with the practice of aquaculture dating back to centuries ago. Nepal has been prior in producing its native fish species along with non-native species of fish. With the abundance of water resources in the forms of lakes and reservoirs, aquaculture can be improved and mechanized. RAS has already been approved and established throughout the world while Nepal is still lagging behind. Our dependency on agriculture and fish farming has only been increasing. In order to meet the increasing demand, technologies has to be introduced for easy and sustainable farming practices. Although new to Nepal, RAS can be very benefiting and sustainable practice of fish farming. Minimal studies have been conducted so far in this field of technology. Encouraging new researchers can be a way to improve the practice. Given that RAS can be established despite the geographical limitation and variability, aquaculture can be spread throughout the country. Since, it is a modular form of system, it can easily be set up. Furthermore, the high-density culture provides high production in limited space and time. Therefore, for sustainable farming practices, RAS should be promoted throughout the country.

Oreochromis niloticus, also known as Nile Tilapia, belongs to order Cichliformes and family cichilidae. It is known for its easy growth and high tolerance and thus is cultured throughout the world. Tilapia is often called the chicken of fish. Although being invasive in nature in natural environment, Tilapia are very productive in cultured environment.

Tilapia are mostly herbivores in nature but are sometimes omnivores specially during young. They feed mostly on phytoplankton and algae. However, when released outside in natural ecosystems, Tilapia are invasive. Because of its invasive nature, there is still a worldwide skepticism about the culture of Tilapia. The production of Tilapia has grown by 3.3% in 2020 exceeding 6 million tones for the first time (FAO, 2020). In natural habitat, tilapia is brownish or greyish overall with indistinct banding on their body. During breeding, the color of males turns reddish, especially on the fins. Nile tilapia are diurnal, similar to trout and salmon which exhibits a behavioral response to light as a main factor contributing to its feeding behavior. It has high reproductive rate which benefits tilapia in being invasive species. Despite the equal feeding, males tend to grow larger than females due to a higher efficiency of converting food to body weight. Because of this reason, monosex tilapia are preferred than female in aquaculture. During breeding stage, the male gets territorial and sexual competition amongst the male also increase leading to large variation in reproductive success for individuals in a group.

Cyprinus carpio, commonly known as Common Carp, is a freshwater fish of eutrophic waters in lake and large rivers in Europe and Asia. Although, the native population has been listed as vulnerable to extinction by the International Union for Conservation of Nature (IUCN), the species has been domesticated widely in the world. Often considered as invasive species, it has been listed in the list of the world's 100 worst invasive species. It belongs to the order Cypriniformes and family Cyprinidae. Morphologically, it has a robust build with a dark gold sheen prominent on its head. The pectoral fins are large and a tapering dorsal fin. It has downwards-turned mouth of the carp with two pairs of barbels. In adequate growth condition, common carp can grow to massive size. This fish is very tolerant to most conditions but prefer large water bodies of slow or standing water. When schooling, they prefer to be in groups of five or more. Naturally, they are found in temperate climates in fresh and slightly brackish water with pH of 6.5-9 and temperature of 3-35°C. The spawning begins at 17-18°C. Due to their high tolerance, they can survive winter in a frozen-over pond as long some free water remains below the ice.

The diet of carp is of wide range from herbaceous diet of aquatic plants to insects, crustaceans, zooplanktons, crawfish and benthic worms. They feed throughout the day but are most intensive feeder at night and around sunrise. During spawning, a single female can lay 300,00 eggs in a single spawn. They spawn mainly during spring with rising water temperatures and rainfall but they also can spawn multiple times in a season. In commercial carp farm, the spawning is induced often by the process called hypophysation where lyophilized extract is injected into the fish. In Nepal, carps are widely cultured in the sub tropic zone. Since, they are easy to grow so always lies in the first choice of farmers. The experimental fishes of this study were brought from Centre for Aquacutlure Agriculture Research and Production, Kathar, where breeding of carp is done every year.

Tor putitora, the Himalayan Mahseer or Golden Mahseer, a popular game fish is an endangered cyprinid fish found in rapid streams, riverine pools and lakes in the

Himalayan region. In Nepal, it is locally known as “Sahar” or “Satta”. It is believed to be the largest species of mahseer which can grow up to 2.75m in length. It is omnivores in nature. The body above its lateral line is golden in color at adult.

In Nepal, it is found in fast moving water resources of the Himalayan foothills especially in rivers Kaligandaki, Trishuli, Sunkoshi, Narayani and Karnali. But in recent years, due to the increase in destructive ways of fishing such as electro-fishing, dynamiting, poisoning, overfishing, illegal mining, hydroelectric plants and habitat degradation the steady decline of population of mahseer increases day by day. Conservationists have expressed serious concern about the declining population and destruction of habitats of mahseer. Promoting recreational fishing can conservation of mahseer. Even in sport fishing, catch and release technique can help in maintaining population of mahseer. The effective collaboration between anglers, farmers, policy makers, ecologist and other stakeholders can help in raising awareness and finding out the solution for the conservation of mahseer in Nepal.

Growth of fish is dependent on a wide range of positive or negative impacting factors. Studies show that growth of fish in aquaculture mainly depends on feed consumption and quality (Slawski et al., 2011); stocking density (Ma et al., 2006); biotic factors such as sex and age (Imsland and Jonassen, 2003); genetic variance; and abiotic factors such as water chemistry, temperature (Imsland et al., 2007), photoperiod (Imsland and Jonassen, 2003), and oxygen level (Bhatnagar and Devi, 2013). Therefore, successful management of fish ponds requires an understanding of water quality, which is determined by abiotic factors such as temperature, dissolved oxygen (DO), transparency, turbidity, water color, carbon dioxide, pH, alkalinity, hardness, unionized ammonia, nitrite, nitrate, primary productivity, biological oxygen demand (BOD), plankton population among others (Bhatnagar and Devi, 2013). A study by Bryan et al. (2011) conducted in Pennsylvania in 1998 on 557 pond owners established that 10% of the respondents had experienced water quality problems in their ponds ranging from muddy water to toxicity leading to fish kills.

1.1 OBJECTIVES

1.1.1 GENERAL OBJECTIVES

- To study the growth performance of *Oreochromis niloticus*, *Cyprinus carpio* and *Tor pitutora* in Recirculating Aquaculture System.

1.1.2 SPECIFIC OBJECTIVES

- To assess the growth of *Oreochromis niloticus, Cyprinus carpio* and *Tor pitutora* in Recirculating Aquaculture System.
- To analyze the Feed Conversion Ratio of *Oreochromis niloticus*, *Cyprinus carpio* and *Tor pitutora.*

1.2 SIGNIFICANCE OF THE STUDY

Recirculating Aquaculture System is still a fresh technology in Nepal. With the limited access of land area and water, fishes can be produced in high volume outnumbering the total volume of fish produced in ponds of equivalent area. RAS require less direct land and water, allowing for great stocking densities, but they do require a lot of energy, resulting in high production costs and waste disposal issues. When the benefits of improved fish performance outweigh the additional expenses, RAS technologies are usually favorable. RAS's grow-out activities are increasingly focusing on high-value species. The prospect of aquaculture can be uplifted with the advancement of technology and it can be achieved only through the further research and investigation. This study will study the growth performances of three species which are of great economic value in fish industry in Nepal and thus will promote the culture of these fishes along with the RAS system in Nepal.

CHAPTER-TWO

2. LITERATURE REVIEW

With Denmark being the first ever country to run Recirculating Aquaculture System for eel production, the present RAS has been not only limited to eel production but includes wide ranges of both marine and fresh water aquatic lives. (Warren-Hansen, 2015) Besides fishes, RAS also facilitates the culture and production of other aquatic lives including shrimps, lobster, crabs, etc. The idea of culturing fishes in indoor climate in limited land space and water access has not only developed the aquaculture sector throughout the world but has also been proven as a global method for farming in limited land areas and better use of land areas. It has also been a defeating idea for requirement of more food production and global hunger. (Warren-Hansen, 2015).

The possibility thanks to these systems to handle, store and treat waste products accumulated during the growth of farmed fish represent a key factor for the development of environmentally friendly management of aquaculture production systems (Piedrahita, 2003; van Rijn, 1996). They adopt a closed farming system (or recycled) that allows the reuse of farm water thanks to a series of filtrations, thus limiting not only the removal - 10 - from natural water resources, but also the impact on the environment reducing the volume of waste generated treated in the same system (Buono, 2005; Lahav et al., 2009).

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Recent decades have witnessed a rapid growth and development of aquaculture systems for the intensive rearing of fish (van Rijn, 1996). This was in response to the increasingly high worldwide per capita demand (16.7 kg) showing a steady upward trend for the coming decade and where aquaculture provides 47% (FAO, 2009). In order to alleviate the pressure of fishing on marine stocks, it is necessary that the production (especially fish) should be accelerated through aquaculture (Tal et al., 2009). This production increasing, in addition to be economically viable, also takes into account the impact that it has on resources (environment, water availability, location on land, etc.) (Schneider et al., 2007; Zohar et al., 2005).

Carp is the most extensively cultured fresh water fish species in the world (Zhou et al, 2004). Carp is easy to rear fish. It has high tolerability in extreme water parameters. It is popular in commercial aquaculture because of fast growth rate, high environmental tolerance, ease of handling, utilize diet properly and also high stocking density (Kirpatchnikov, 1999). It has fast growth rate and its maturation at early stage and breeding habit retard growth through competition for food and space (Basavaraja et al, 1997).

Growth of fish is dependent on a wide range of positive or negative impacting factors. Studies show that growth of fish in aquaculture mainly depends on feed consumption and quality (Slawski et al., 2011); stocking density (Ma et al., 2006); biotic factors such as sex and age (Imsland and Jonassen, 2003); genetic variance; and abiotic factors such as water chemistry, temperature (Imsland et al., 2007), photoperiod (Imsland and Jonassen, 2003), and oxygen level (Bhatnagar and Devi, 2013). Therefore, successful management of fish ponds requires an understanding of water quality, which is determined by abiotic factors such as temperature, dissolved oxygen (DO), transparency, turbidity, water color, carbon dioxide, pH, alkalinity, hardness, unionized ammonia, nitrite, nitrate, primary productivity, biological oxygen demand (BOD), plankton population among others (Bhatnagar and Devi, 2013). A study by Bryan et al. (2011) conducted in Pennsylvania in 1998 on 557 pond owners established that 10% of the respondents had experienced water quality problems in their ponds ranging from muddy water to toxicity leading to fish kills

The stocking density of Tilapia varies from 80 to 100m3 with production ranging from 1.5tonnes per hector in rustic ponds to 25 tones per hector in raceways annually (Camacho-Berthely et al.,2000).

The main characteristics of RAS is the ability to support extremely high stocking densities and high net production compared with a regular open aquaculture systems

(Timmons et al., 2002). To clarify, it is possible to produce over 45 tons of fish in a 464m2 building through RAS whereas, an 8 hector of outdoor ponds would be required to produce an equal volume of fish (Helfrich & libey, 1990). However, RAS consume approximately 250-1000l/kg of fish and discharge less effluent in comparison with open systems which reduces the volume and cost of wastewater treatment (Shnel et al., 2002). The water condition is reconditioned by clarification, biological filtration and aeration which allows the maximum volume of water to be reused and only 10% of the total daily flow is replaced by new water (Timmons et al., 2002). Most authors report performance data from the grow out stage. Suresh & Lin (1992), reported a relatively low growth (0.77, 0.65 and 0.64 g per day) of red tilapia Oreochromis aureus stocked in RAS at 50, 100 and 200 fish m-3 (3.6, 7.5, 15.3 kg m-3) for 70 days. Ridha & Cruz (2001) reported high growth rate (1.17g per day) and 97.6% of survival in Nile tilapia reared in RAS at 166 fish m-3(10.3 kg m-3). Bailey et al. (2000) performed an experiment to study the intensive production of Nile tilapia fingerlings (4.3 g) in RAS. Fish stocked at 200 fish m-3 grew slightly faster (0.78 g day-1) than those stocked at 450 fish m3 (0.60 g day-1).

The water parameters were maintained identical throughout the culture period. For the maintenance of temperature, solar heater was used during winter. Water was changed when necessary to maintain the water parameters. Each water quality factor interacts with and influences the other parameters, sometimes in complex ways (Joseph et al. 1993). Research has shown that a temperature range between 25 and 320C is ideal for tropical fish culture (Bolorunduro and Abdullah, 1996).

In recent years, in support of golden mahseer, the biological investigations had already commenced and commendable success on production of stocking material through artificial fecundation have been achieved, and attempts are being made to assess their culture feasibilities (Tripathi 1977; Kohli et al. 2005; Joshi et al. 2007). . Golden mahseer, an indigenous coldwater fish with desirable characteristics such as amenability to culture in captivity, capacity to accept supplementary feed and ability to tolerate wide range of environmental parameters, forms an interesting candidate for aquaculture in coldwater regions of India (Cordington 1939; Jhingran & Sehgal 1978; Chauhan et al. 2007). Thus the development of fisheries of this species will play a significant role in country’s economy. Nutritional research on golden mahseer has mainly focused on the development of diet (Mohan & Basade 2005; Keshavnath et al. 2007); less attention has been given to the practical issues of feed management. Some researcher's findings demonstrate that the lowest food conversion and maximum growth rates can be achieved at the optimal feeding frequency (Andrews & Page 1975; Siraj et al. 1988). Feeding frequency, however, may affect food conversion, variability in fish size and loss of water-soluble nutrients from feed (Piper 1982). Suitable feeding frequency also affects the growth, survival and condition factor of fish (Pfeiffer & Lovell 1990; Kayano et al. 1993; Vega et al. 1994; Sager &Winkelman 2006). This suggests that three meals per day is the optimum feeding frequency for golden mahseer early fry. Optimum feeding frequency for different fish species varies. Growth rates were higher for common carp, Cyprinus carpio (Charles et al. 1984), rainbow trout, Oncorhynchus mykiss (Ruohonen et al. 1998) and tambaqui, Colossoma macropomum (Silva et al. 2007) when fed three meals per day.

Further it was observed that feeding frequency was strongly influenced by the time of gastric evacuation (Riche et al. 2004). Nile tilapia, Oreochromis niloticus, had an appetite 4 hours after food was offered; therefore a feeding management that offers meals every 4 hours is the best strategy for that species growth. Growth rates were higher for common carp, Cyprinus carpio (Charles et al. 1984), rainbow trout, Oncorhynchus mykiss (Ruohonen et al. 1998) and tambaqui, Colossoma macropomum (Silva et al. 2007) when fed three meals per day.

CHAPTER-THREE

3. MATERIALS AND METHODS

3.1 MATERIALS

1. Fiberglass Reinforced Plastics (FRP) tanks
2. Water pump
3. Aerator
4. Air stones
5. Bio-media
6. Drum filter
7. PVC pipes
8. Fish species
9. Fish feed
10. Freshwater master test kit
11. Thermometer
12. pH meter
13. Measuring scale
14. Digital weighing balance
15. Fish net

3.2 EXPERIMENTAL SITE AND SETUP

The study was done in the premise of FreshAcres Agriventure Pvt. Ltd. Of Hattiban, Lalitpur from April 2020 to Nov 2021. Three FRP circular tanks of each 3m diameter with height of 1.2m around the circumference and 1.5m in the center were set up ($8m^3$). The tanks were circulated in a loop flowing through filtration process and travelling back to respective tanks. The filtration process included of mechanical filtration and biological filtration. For the mechanical filtration, drum filter was installed. The total suspended solids (TSS) were filtered through the drum filter. From the drum filter, the water was processed through biological filtration in which the total ammonia nitrogen (TAN) which is considered harmful for the fish is converted to less harmful nitrate through the process called nitrification and the resulted nitrate was converted to nitrogen which is expelled through the system through degasser.

Along with the filtration, air pump was also fitted for oxygen supply to the fishes. The experiment was set up with 3 individual fish tanks and replications of each. Each fish was reared in a major tank and replication tank for 24 weeks.

The number of stocking density of fishes in each tank consists of 200 fingerlings. Three set up with 3 replication were made as follows:

T1 –Tank set up containing Nile Tilapia

Replications- R1, R11, R12

T2- Tank set up containing Common Carp

Replications- R2, R21, R22

T3- Tank set up containing Golden Mahseer

Replications- R3, R31, R32

Each species of fish was cultured for 24 weeks in the identical growing environments.

3.3 RAS TANK SET UP

Three experimental tanks were set up for the experiment. The tanks were made of fiberglass with cemented flooring and were sealed with resin and silicon. The tanks were designed circular for easy removal of wastes from the tank through central drain. The inlet and outlet were made for water drainage and water input. From the outlet of the tank, water was passed through filtration system for purification of water and was returned back to the tank through inlet. The water volume of each tank was $8m^3$. Water was sourced from nearby stream for easy transport. It was then disinfected with UV treatment and potassium permanganate.

3.4 EXPERIMENT DESIGN AND LAYOUT

Three species of fish were cultured for analysis of growth performances. Nile Tilapia, Common Carp and Golden Mahseer were used for the experiment. The time frame was 18 months. In the first 24 weeks, Nile Tilapia was cultured. The second The first 6 months were used for the culture of Nile Tilapia, the second 6 months for Common Carp and later were used for Golden Mahseer. The water quality parameters were maintained identical throughout the time period for more concrete comparison data. The season and weather were unrelated throughout the experiment because the system was indoors and insulated with its own microclimate.

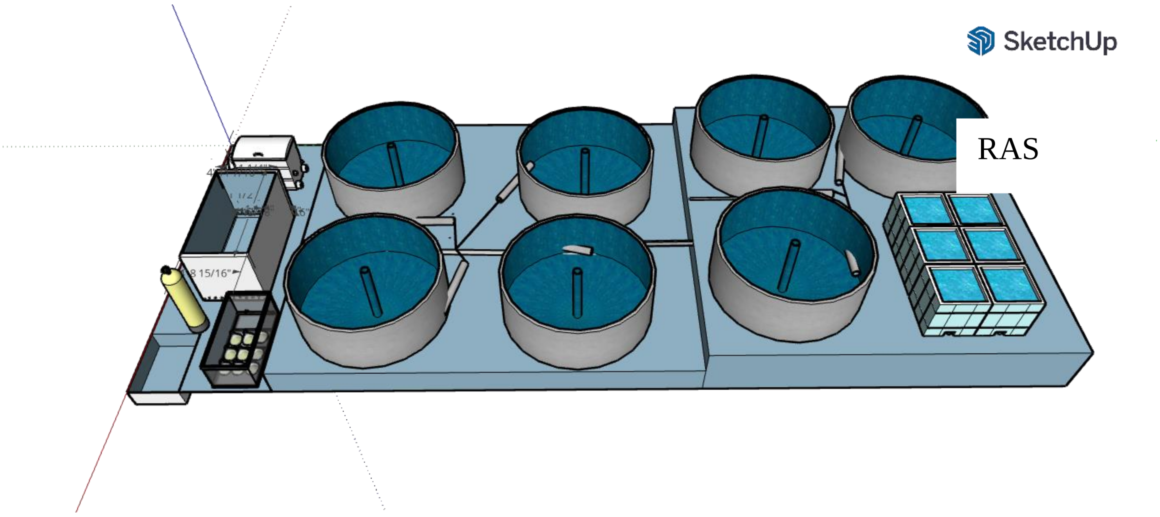

Figure 2: Recirculating Aquaculture System design

3.5 Selection of Feed and Feed Frequency

All of the three species of studied fish were collected and transported from Center for Aquaculture-Agriculture Research and Production (CAARP), Kathar, Chitwan to the study site. 200 fingerlings each of Common Carp, Nile Tilapia and Golden Mahseer were taken for the study. The fishes were fed commercial floating feed Mega feed with protein of 35%. The fish were fed 3 times per day with 3% of the body weight. The size of Common Carp was 4.8 g on average while the size of Nile Tilapia was weighed 5g on average and the size of mahseer was 0.48g on average.

3.6 Feeding Techniques

In the growth tanks, they were fed 5% of body weight every day. Locally available commercial floating fish feed were used for all three species. In the initial 30 days, 1mm pellet were fed. The fish were sampled every month for their weight measurement and thus intake in feed was increased as per the weight gained by the fish. The fish were reared and fed for 6 months. They were fed commercial fish feed with crude protein of 35%. The fish were fed three times daily, in the morning (8:00 am), during the day (2:00 pm) and at night (8:00 pm).

3.7 Fish Sampling and Measurements

Random sampling was done for the measurements of fish. For the precise measurement of body weight, digital balance was used and for the measurement of body length vernier caliper was used in the initial days of the culture and later scale was used. Fish was sampled every month with random sampling. Altogether, twenty samples were collected from each tank. During the sampling days, they were not fed. Fish were sampled early in the morning before their feed time to measure the adequate body weight.

3.8 Installation of Aerator

Throughout the study period, the tanks were facilitated with aerator for supply of oxygen demand. The aerator was let in run 24 hours every day throughout the cycle. Four air stones were allocated in each tank for air supply.

3.9 Growth parameters

Growth performance of Nile Tilapia, Common Carp and Golden Mahseer were calculated in terms of final body weight, absolute growth, absolute growth rate and specific growth rate. They were all computed in relative terms for the comparisons. The growth parameters were calculated following the method described by Bagenal (1978) as follows:

Weight gain (WG) = Final weight- initial weight

Length Gain (LG)= Final length-initial weight

Average daily weight gain (ADG)= (Final weight- Initial weight)/Days

Average daily length gain (ADL)= (Final Weight-Initial weight)/Days

Feed Conversion Ratio (FCR)= Total feed(g)/Weight gain(g)

Specific Growth Rate (SGR) **= (Ln (Wt)-Ln(W0)) *100/t(d)**

Wt= final weight

W0= initial weight

T= time

Survival Rate (SR)%= No. of fish survived/no. of fish leased*100

CHAPTER-FOUR

4. RESULTS

4.1 Growth Performance of Tilapia

The initial mean weight of Tilapia fingerlings were in three replications R1,R11,R12 were 5.007±0.36g, 4.9±0.45g and 5.12±0.2g. Final mean weight were 227.115±15.56g, 244±14.19g and 234±11.3g. Weight gain was 222.107g, 239.1g and 228.88g respectively in three replications. Similarly, length gain was 11.3cm, 11.6cm and 11.4cm in R1, R11 and R12 replications. Out of the replications, R11 had highest weight gain along with the highest length gain. Similarly, average daily weight gain was highest in R11 with 1.32g per day and average daily length gain was 0.062cm per day. Feed conversion ratio was 2.9, 2.7 and 2.81 in R1, R11 and R12. Survival rate was 90%, 85% and 89% respectively in three set ups. (Table 4.1.)

Table 4.1: Growth Performance of Tilapia

S.N.	**Fish species**	**Tilapia T1**			**Mean**
1	**Replications**	**R1**	**R11**	**R12**	
2	Mean initial weight (g)	5.007±0.36	4.9±0.45	5.12±0.2	5.01±0.09
3	Mean final weight (g)	227.114±15.56	244±14.19	234±11.3	235.107±6.92
4	Weight gain (g)	222.107	239.1	228.88	230.029±6.98
5	Length gain (cm)	11.3	11.6	11.4	11.43±0.124
6	Average daily weight gain (g)	1.26	1.32	1.27	1.28±0.026
7	Average daily length gain(cm)	0.06	0.062	0.061	0.061±0.0008
8	Feed Conversion Rate(FCR)	2.9	2.7	2.81	2.8±0.081
9	Specific growth rate (SGR)	3.001	3.042	3.01	3.01±0.72
10	Survival Rate (SR) %	90	85	89	88±2.16

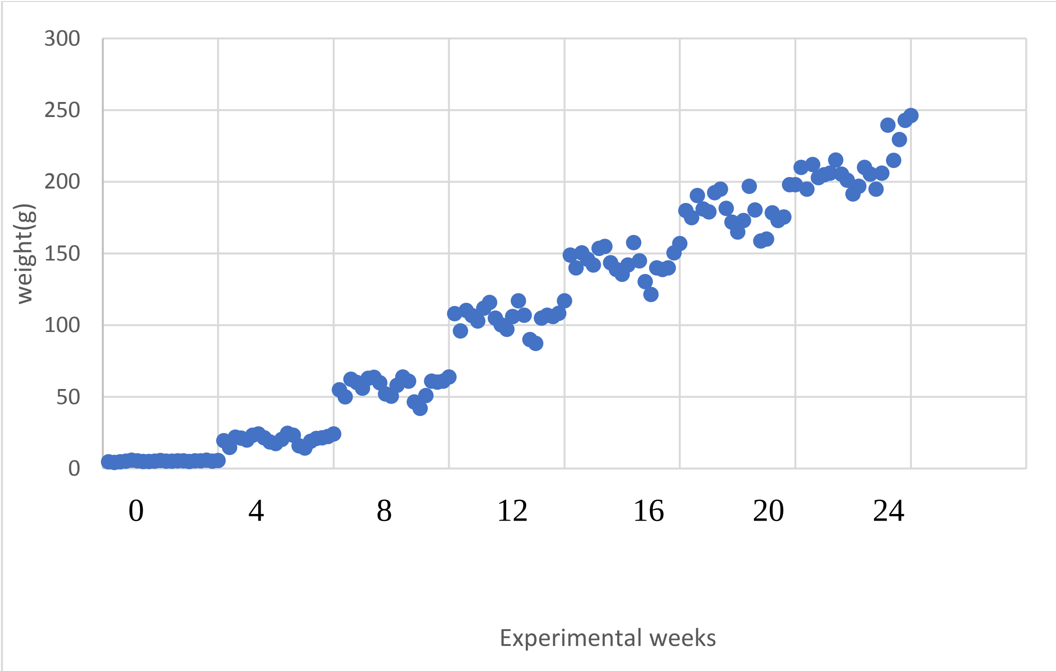

Figure 3: Growth rate of Tilapia in Set up R1

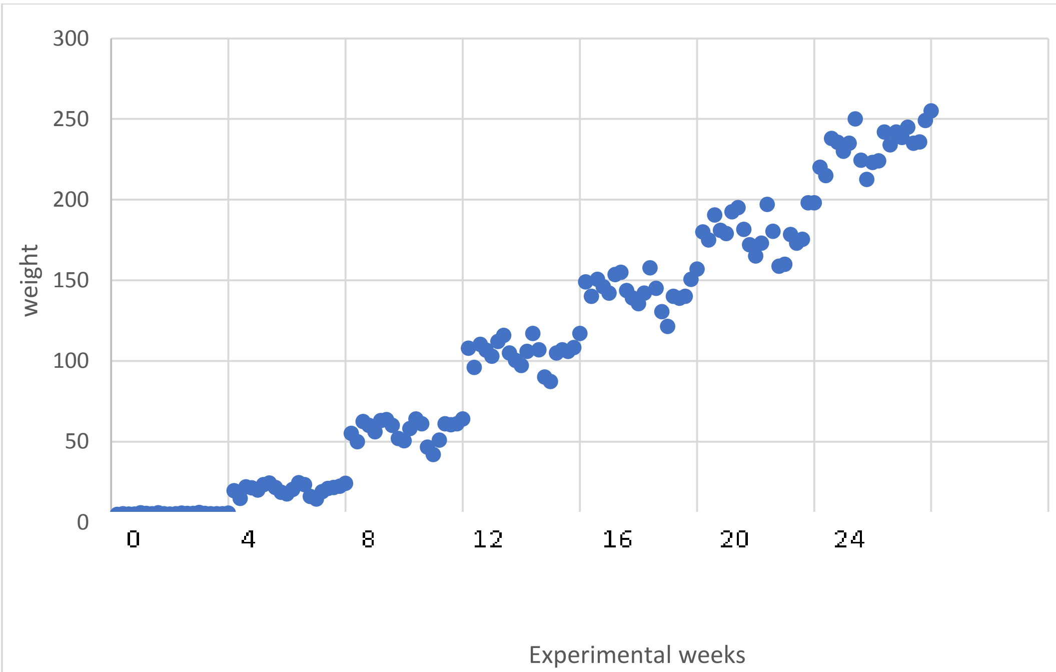

Figure 4: Growth rate of Tilapia in Set up R11

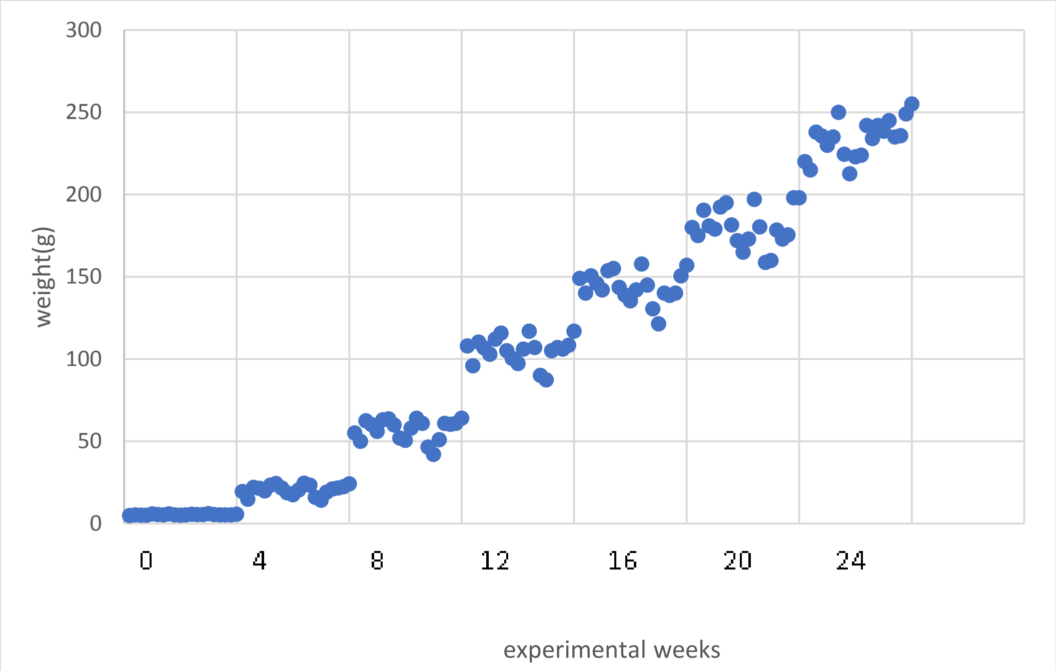

Figure 5: Growth rate of Tilapia in Set up R12

4.2 Growth performance of Common Carp

Common carp showed highest growth rate in comparison to other two species. The initial weight of the three replications were 4.81±0.8g, 5.12±0.6g and 4.5±0.6 of R2, R21 and R22 respectively. The final weight of three replications were 1252.3±82.34g, 1234±79.3g and 1232±73.95g. The weight gain were 1247.49g, 1228.94g and 1227.5g. Similarly, the length gain was noted to be 20cm, 21.2cm and 20.5cm respectively. The average daily weight gain was noted to be 6.9g, 6.8g and 6.8g respectively. Likewise, the average daily length gain was observed to be 0.1cm, 0.11cm and 0.11cm respectively. The feed conversion ratio was found to be 2.7, 2.4 and 2.5 and specific growth rate was found to be 3.06, 3.05 and 3.1 respectively. Similarly, the survival rates were 96%, 85% and 88% simultaneously in three replications. (Table 4.2.)

Table 4.2: Growth performance of Common Carp

S.N.	Fish species	Common Carp T2			Mean
1	Replications	R2	R21	R22	
2	Mean initial weight (g)	4.81±0.8	5.12±0.6	4.5±0.6	4.81±0.25
3	Mean final weight (g)	1252.3±82.34	1234±79.3	1232±73.95	1239.433±9.28
4	Weight gain (g)	1247.49	1228.94	1227.5	1234.643±9.1
5	Length gain (cm)	20	21.2	20.5	20.567±0.49
6	Average daily weight gain (g)	6.9	6.8	6.8	6.83±3.15
7	Average daily length gain(cm)	0.1	0.11	0.11	0.106±0.004
8	Feed Conversion Rate (FCR)	2.7	2.4	2.5	2.53±0.12
9	Specific growth rate (SGR)	3.06	3.05	3.1	3.07±0.02
10	Survival Rate (SR) %	96	85	88	89.67±4.64

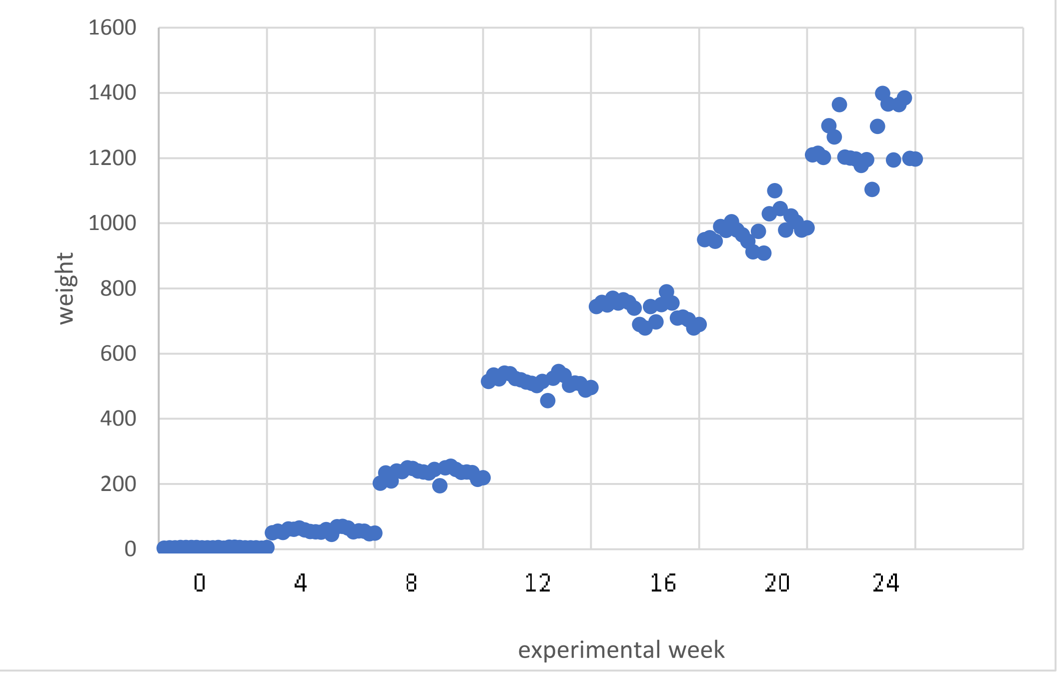

Figure 6: Growth rate of Common Carp in Set up R2

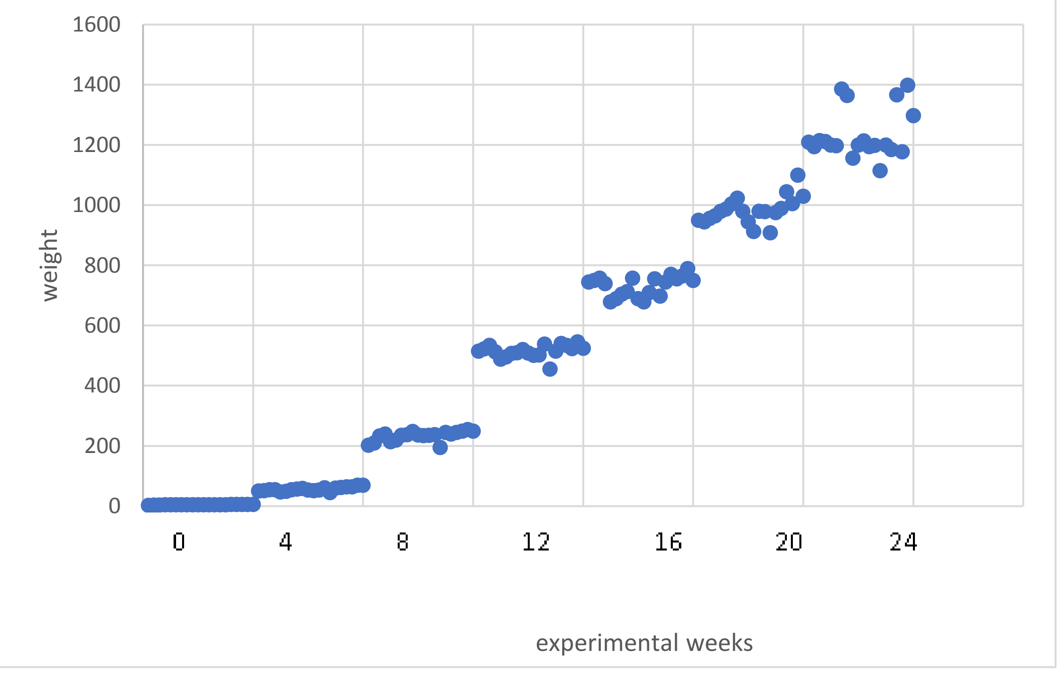

Figure 7: Growth rate of Common Carp in Set up R21

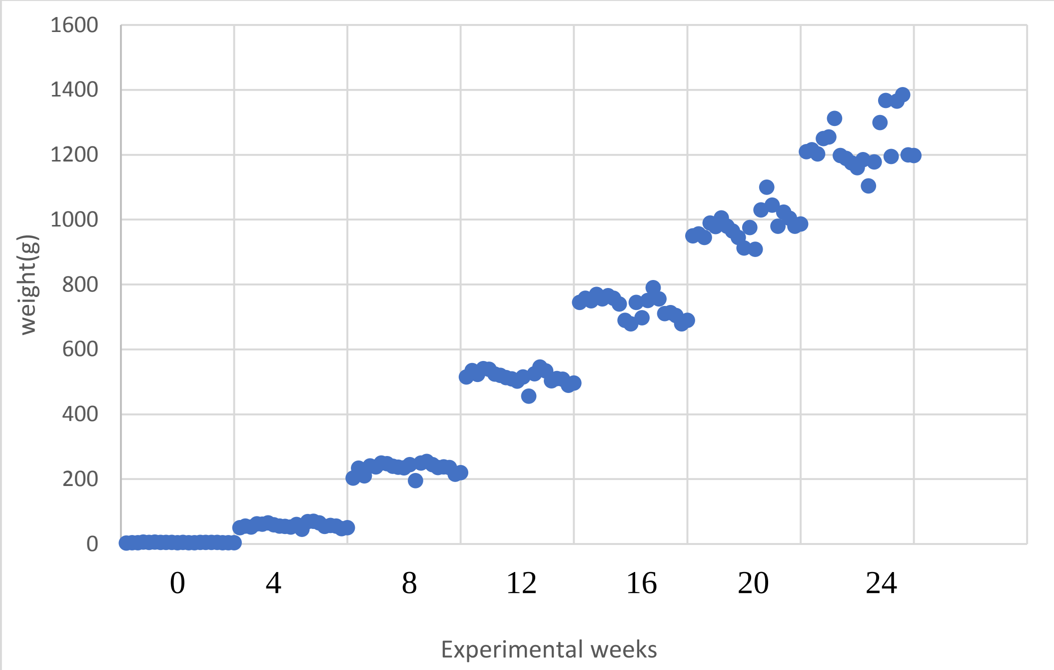

Figure 8: Growth rate of Common Carp in Set up R22

4.3 Growth performance of Mahseer

The initial weight of Mahseer was found to be 0.5±0.16g, 0.45±0.06g and 0.51±0.03g. The final weight was found to be 45.73±1.99g, 44.8±1.98g and 46.8±2.19g. Similarly, the weight gain was found to be 45.23g, 44.35g and 46.29g respectively in R3, R31 and R32. Length gain was found to be 4.9 cm, 4.8 cm and 4.7 cm. Average daily weight gain was found to be 0.25g, 0.24g and 0.25g respectively. Average daily length gain was found to be 0.02cm, 0.026 cm and 0.026 cm in three tanks respectively. Also, the feed conversion rate was found to be 3.39, 3.36 and 3.45 along with specific growth rate of 2.4, 2.55 and 2.5 respectively. Survival rate was found to be 88%, 87% and 86% respectively in three tanks of mahseer. (Table 4.3.)

Table 4.3. Growth Performance of Mahseer

S.N.	**Fish species**	**Golden Mahseer T3**			**Mean**
1	**Replications**	**R3 (g)**	**R31 (g)**	**R32 (g)**	
2	Mean initial weight (g)	0.5±0.16	0.45±0.06	0.51±0.03	0.51±0.05
3	Mean final weight (g)	45.73±1.99	44.8±1.98	46.8±2.19	45.78±0.8

4	Weight gain (g)	45.23	44.35	46.29	45.29±0.79
5	Length gain (cm)	4.9	4.8	4.7	4.8±0.08
6	Average daily weight gain (g)	0.25	0.24	0.25	0.24±0.004
7	Average daily length gain(cm)	0.02	0.026	0.026	0.024±0.0028
8	Feed Conversion Rate (FCR)	3.39	3.36	3.45	3.4±0.037
9	Specific growth rate (SGR)	2.4	2.55	2.5	2.48±0.062
10	Survival Rate (SR) %	88	87	86	87±0.81

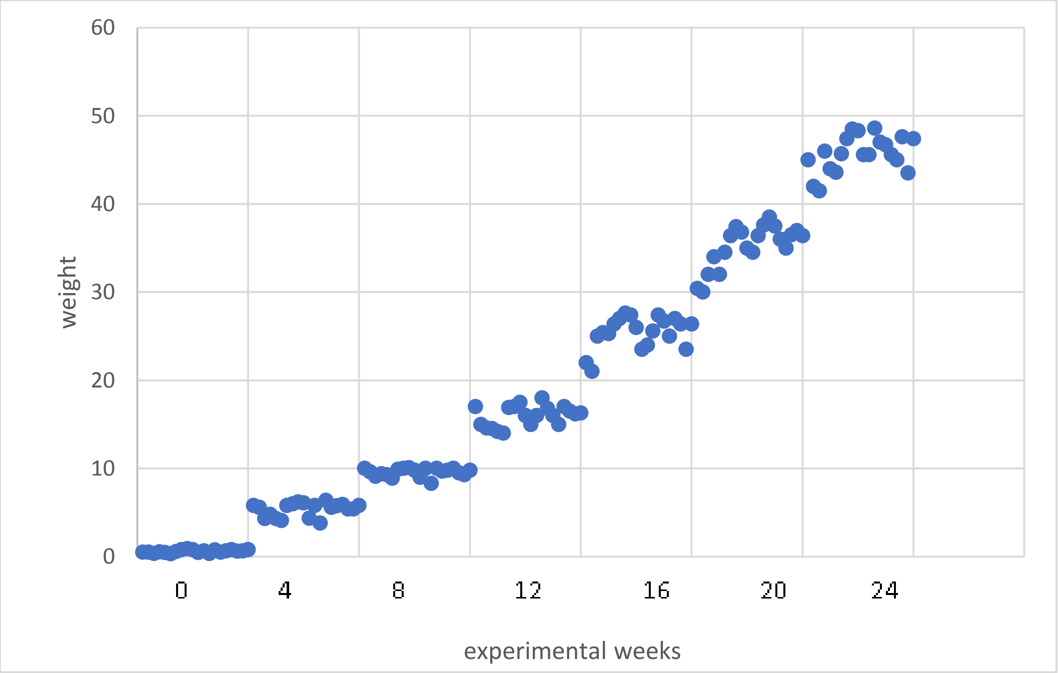

Figure 9: Growth rate of Mahseer in Set up R3

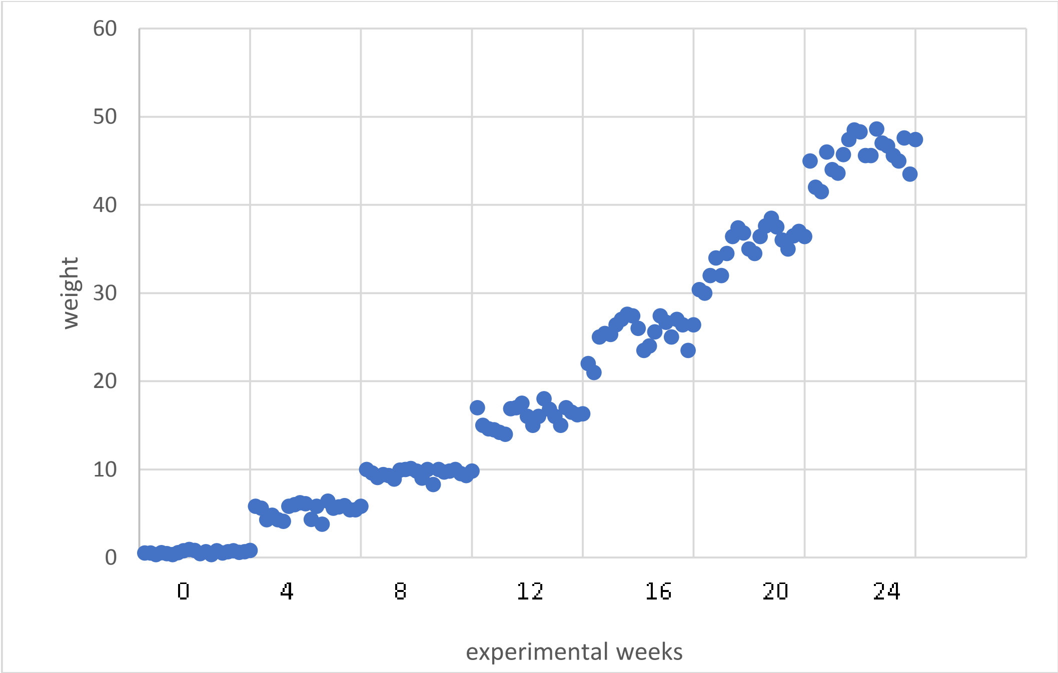

Figure 10: Growth rate of Mahseer in Set up R31

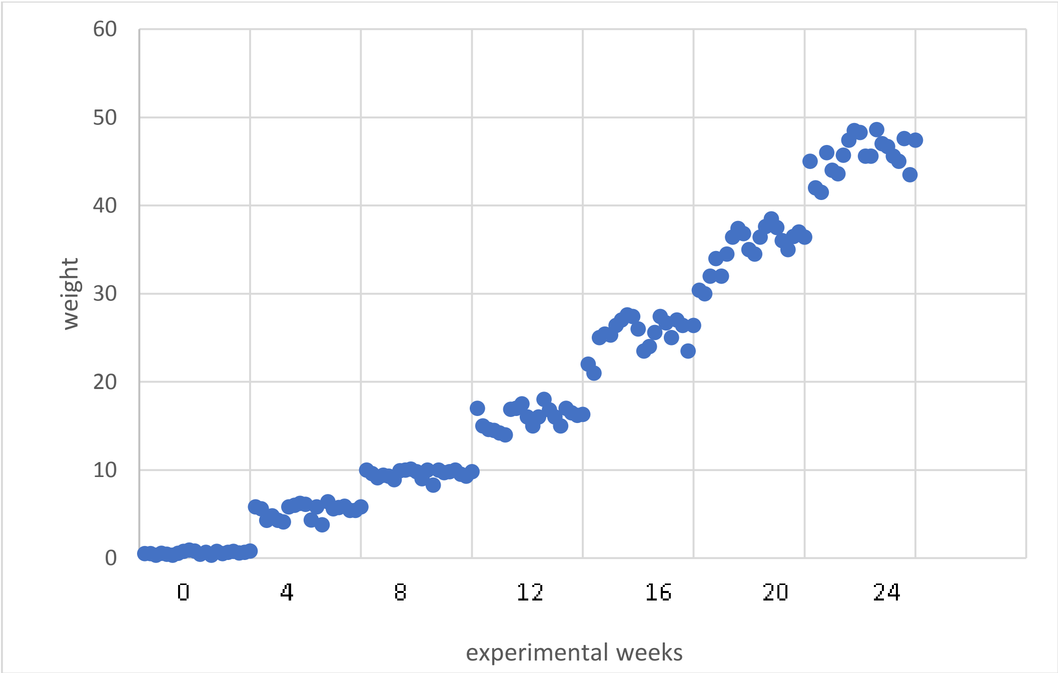

Figure 11: Growth rate of Mahseer in Set up R32

4.4 Feed Conversion Ratio (FCR)

The Feed Conversion Ration of Tilapia was obtained to be 2.9, 2.7 and 2.81 in R1, R11 and R12 respectively. While the FCR was found to be 2.7, 2.4 and 2.5 in R2, R21 and R22 respectively in Common Carp. 3.39,3.36 and 3.45 FCR was obtained in Mahseer in R3, R31 and R32 replications.

4.5 Survival rate (SR) %

The Survival rate was found to be 90%, 85% and 89% in Tilapia tanks R1, R11 and R12 while in Common carp was obtained to be 96%, 85% and 88% in R2, R21 and R22 tanks. Similarly, the survival rate of mahseer was noted to be 88%, 87% and 86% in R3, R31 and R32 tanks.

CHAPTER-FIVE

5. DISCUSSION

5.1 Growth performance of Nile Tilapia

Sweilum (1995) discovered that as the stocking density was reduced, the length and weight of the two rearing fishes (Nile tilapia and carp) increased marginally. Stocking density was found to have a substantial impact on the size, size variation, percentage survival, and productivity of tilapia fry (Huang and Chin, 1997). The stocking density in this experiment was 25 fish per m3. The result of weight gain in this study could be due to the lower stocking density. In three replications, weight gain was 222.107g, 239.1g, and 228.88g, respectively. In R1, R11, and R12 replications, length growth was 11.3cm, 11.6cm, and 11.4cm, respectively. R11 exhibited the most weight gain and the most length gain of all the replications. Similarly, R11 had the largest average daily weight gain.

Furthermore, Nile tilapia growth and output are linked to stocking density, as they increase at low densities (Sweilum, 1998). El-Saidy and Gaber (2002) further demonstrated that the lower stocking density resulted in significantly better mean final weight, mean final weight, length increase, SGR, and feed conversion ratio. Furthermore, Kheir and Saad (2003) demonstrated that for Nile tilapia, the lowest stocking rate resulted with the highest final weight, weight gain, specific growth rate, feed conversion ration, and protein efficiency ratio. Bakeer et al. (2006) recently concluded that stocking density had substantial influence on final body weight and survival, with lower stocking density being preferred. Finally, Alam (2009) concluded that the highest stocking density [150 monosex male Nile tilapia (2.8 g starting weight/m3) of monosex male Nile tilapia (2.8 g beginning weight/m3) of monosex male Nile tilapia (2.8 g initial weight).

5.2 Growth performance of Common Carp

Weight gain of 1.53 g, daily growth of 0.02 gday-1, specific growth of 7.37 percent day-1, feed conversion of 2.82, and survival rate of 72.32 percent were recorded in RAS-cultured common carp (Mojer et al. 2021). The average mean initial weight of common carp was 4.80.25g, whereas the mean ultimate weight was 1239.439.1g.

According to the estimates. 1234.639.1g was the average weight gain. Similarly, the mean length gain was 2.560.49cm, the average daily weight gain was 6.80.04g, and the average daily length gain was 0.10.004cm, with a specific growth rate of 2.530.12, and an 89.6% survival rate. Carp have a tendency to develop more quickly than other fish. A primary cause of growth variation could be a species-specific difference. It also offers a wider tolerance range for water parameters. Excess protein causes excessive levels of ammonia generation, which might impact voluntary feed intake and fish growth (Kaushik and Medale, 1994). Carps may thrive in both closed and open systems. Carp is frequently utilized in RAS around the world due to its high growth rate and tolerance range. It is also commonly used in aquaculture. As a result, the study recommended carp as a suitable fish for aquaculture in a closed system.

Ogino and Satio (1970) found that fish feed with 38 percent protein is suitable for growth in other common carp species. Commercial fish feed with a 35 percent protein content was employed in this study. It's possible that the larger weight gain of fish reported in this study than in Rahman et al. (2006) is due to the better utilization of prepared diet.

5.3 Growth performance of Golden mahseer

The average mean initial weight of mahseer was 0.480.2g, whereas the mean final weight was 45.70.8g, according to the estimates. 45.2907.g was the average weight gain. Similarly, the average daily weight gain was 0.240.004g, and the average daily length gain was 0.0240.008cm, with a specific growth rate of 3.40.03 and an 87 percent survival rate. Mahseer are not usually cultivated in closed tanks. They naturally grow to larger sizes and have a faster growth rate in open ponds. However, the growth rate was found to be quite slow, making mahseer a low priority for culture in RAS.

According to Islam and Tanaka (2004), the optimum dietary levels of crude protein for Mahseer fish (Genus Tor) ranged from 32 to 45 percent crude protein, with factors such as fish size, feeding rate, protein quality of amino acid composition, presence of natural feeds, digestible energy, water quality, and fish stocking density influencing the dietary protein requirement (Kohli et al., 2002). In this situation, similar to Singh, Ebeling, and Wheaton (1999) who raised fish in a rearing tank, the results showed that increasing feeding rate had a substantial impact on total ammonium nitrogen accumulation in the water body. On the other hand, according to Kulkarni (1971), Mahseer fish are bottom feeders and, like other varieties of carps, they are omnivorous. In a scenario comparable to Srikanth (1986), it was shown that Mahseer (Genus Tor) fish may be converted to feeding on commercial diet, which would be beneficial to the farmer in the event of natural food supply shortages. Similar to Kohli et al., (2002), this example discovered that Mahseer fish reared in floating cages in open waters had the best growth response, whereas raising in tanks resulted in poor development due to lower feed intake (Islam & Tanaka, 2004).

This case was most likely linked to improved water quality in bamboo cages because total organic nitrogen accumulation in the water body was reduced by water currency, which was replaced by new water on a regular basis. Bamboo cages were found to be superior to other cages for a variety of reasons, including a lack of total organic nitrogen accumulation in the water body (Kohli et al., 2002). The majority of fish in aquaculture are fed more than one meal each day (Thomassen & Fjaera 1996), and research on feeding frequency has indicated that greater feeding frequency results in increased growth rates (albeit restricted). The best feeding frequency for golden mahseer early fry is three meals each day, according to this data. Despite receiving three meals every day, this study found a discrepancy in mahseer growth, which could be due to specialized species cultivation and cultured in enclosed tanks rather than open ponds.

5.4 Feed Conversion Ratio

Feed conversion ratio (FCR) was determined and provided to the fish as a feed supplement to measure feed consumption. Tilapia's estimated FCR ranges from 1.5 to 2.0 (Watanabe, 2002). The Feed Conversion Ratio of Tilapia was obtained to be 2.9, 2.7 and 2.81 in R1, R11 and R12 respectively. The FCR obtained from this study was higher than expected FCR. Feed was supplied in this experiment using a general strategy that took percentage body weight into account but did not take satiation into account. As a result, the provided feed may go unused. Because the complete amount of provided feed was taken into account when computing the FCR Khan(2013). The mean total production of Tilapia was 5kg/m^3 as per the observation of this study. During the 24 weeks experimental period, the total weight gain rate of tilapia in the RAS is equivalent, which is close to the findings of a previous report on tilapia cultured in a commercial scale RAS (Timmons et al., 2010). Ahmed, et al. [11] recorded survival rate of tilapia ranged from 82 to 90%. In this study, the highest survivability might be the cumulative result of good water quality parameters due to weekly water exchange, quality feed uses and proper maintenance during culture. The Survival rate was found to be 90%, 85% and 89% in Tilapia tanks R1, R11 and R12. Ogino and Satio (1970) found that fish feed with 38 percent protein is suitable for growth in common carp species. Dabrowski (1977) and Pramanik et al. (1997) found different levels of protein needs in carp fry than the current findings. A major driver of growth variance could be differences across species. According to Siddiqui and Khan (2009), the FCR of fish fed 20% protein was the highest (2.397), whereas the FCR of 30 percent, 40 percent, and 50 percent protein-fed fish was 1.964, 1.894, and 2.324, respectively. This study observed 3.39,3.36 and 3.45 FCR in Mahseer in three replications. The findings of the result expressed that the fingerlings fed 45% protein-based feed attained the highest weight, while those fed 35% protein feed attained the lowest weight(Akand et al. 1989). The higher FCR in this study could be the result of low protein diet in mahseer.

CHAPTER-SIX

6. CONCLUSION

An introspective observation was used in this experiment to detect successive growth performance and yield in relation to FCR. This study finds out an outstanding clarification on the growth performance of three different species in different sampling stages in recirculating aquaculture system. It is possible to produce a higher number of fish in such a improved way from a small parcel of land within a short cycle. However, further study needed to explore the relative cost effectiveness of the culture of rohu and tilapia fish in higher stocking density in tank-based aquaculture system. This study will assist the researchers and academicians who wants to culture common carp, mahseer and tilapia in intensive aquaculture system by using floating feed.

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PHOTO PLATES

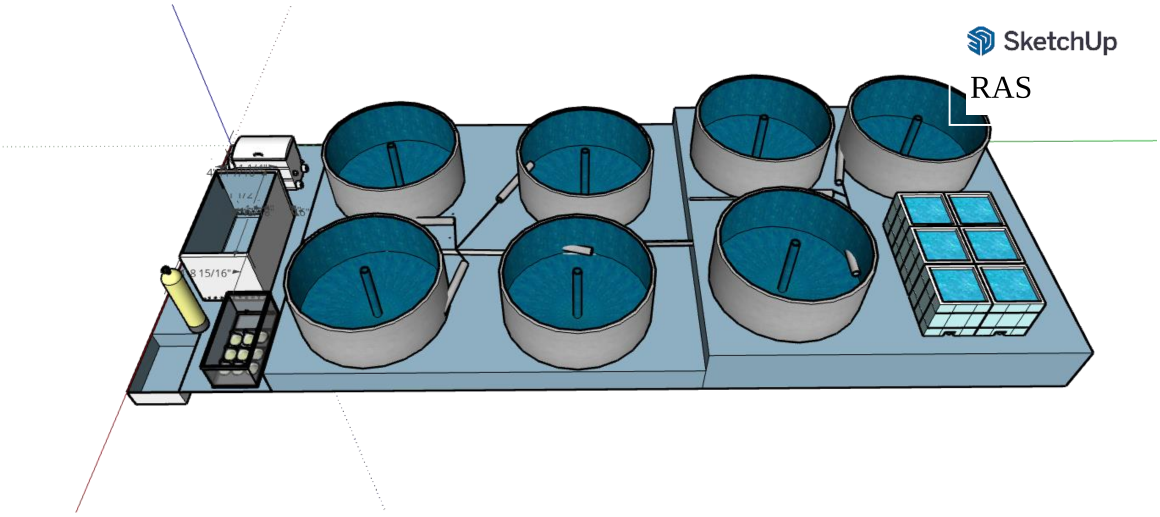

Plate 1. Recirculating Aquaculture Set up

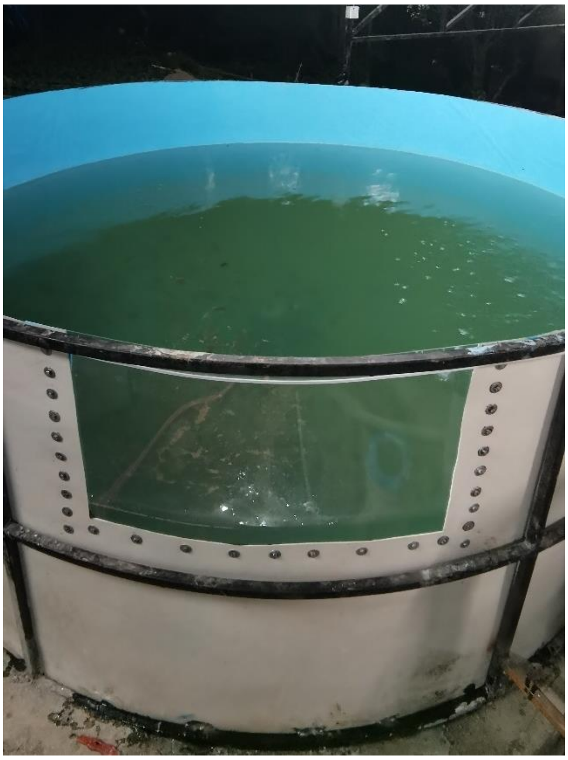

Plate 2. Individual grow tank

Plate 3. Quarantine tanks

Plate 4. Sampling Tilapia

Plate 5. Individual fish tank

Plate 6. Tilapia in tank window

Plate 7. Tilapia in tank window

Plate 8. Measurement of Tilapia

Plate 9. Measurement of fish

Plate 10. Fish Harvesting

Plate 11. Fish weight measurement

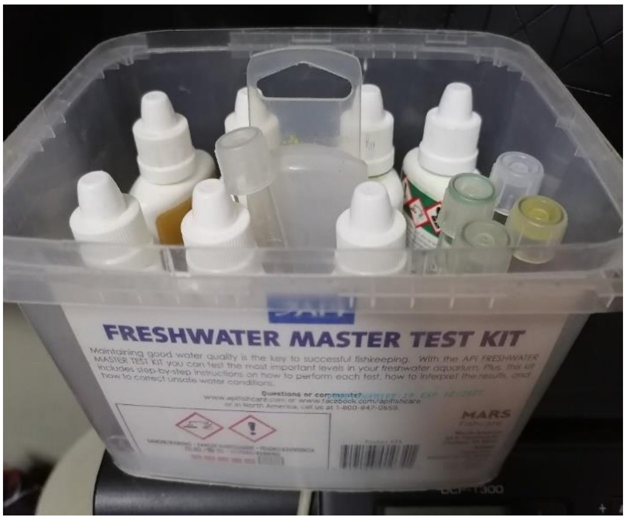

Plate 12. Master test kit

Plate 13: Carp in grow tank

Plate 14: Carps in grow tank

Plate 15: Measurement of Carp