

**Comparative Study of Growth Performance in *Pangasius pangasius* at Different Locations of Varanasi (Uttar Pradesh) at Commercial Recirculatory System**

वाराणसी (उत्तर प्रदेश) के विभिन्न स्थानों पर पुनरावर्तन जलीय कृषि प्रणाली में पंगेसियस पंगेसियस में वृद्धि प्रदर्शन का तुलनात्मक अध्ययन

**ABDUL REHMAN**

**Thesis**

**Master of Fisheries Science**  
(Aquaculture)



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**DEPARTMENT OF AQUACULTURE  
COLLEGE OF FISHERIES  
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND  
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**Thesis**

**Submitted to The**

**Maharana Pratap University of Agriculture & Technology,**

**Udaipur**

**In partial fulfilment of the requirements for**

**The degree of**

**Master of Fisheries Science**

**(Aquaculture)**



**By**

**ABDUL REHMAN**

**2023**

**MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND  
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**CERTIFICATE-I**

**CERTIFICATE OF ORIGINALITY**

The research work embodied in the thesis titled “**Comparative study of growth performance in *Pangasius pangasius* at different locations of Varanasi (Uttar Pradesh) at commercial recirculatory system**” submitted for the award of degree of **Master of Fisheries Science** in the subject of **Aquaculture** to Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan), is original and bonafide record of research work carried out by me under the supervision of **Dr. B. K. Sharma**, Professor & Head, Department of Aquaculture, College of Fisheries, Udaipur. The contents of the thesis, either partially or fully, have not been submitted or will not be submitted to any other institute or university for the award of any degree or diploma.

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**DEDICATED**  
**TO MY**  
**BELOVED FAMILY**

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Date:

(**Abdul Rehman**)

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# 1. INTRODUCTION

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A total fish sale value of USD 401 billion is anticipated for the 179 million tons of fish produced globally in 2018, of which 82 million tons—worth USD 250 billion—were produced through aquaculture. Human consumption accounted for 156 million tons of the total, or 20.5 kg per person annually. 46 percent of the overall production and 52 percent of the fish used for human consumption were produced by aquaculture. (FAO, SOFIA, 2020).

A species of catfish belonging to the family *Pangasiidae* in the Siluriform order is called *Pangasius pangasius* (Hamilton, 1822). One of the most significant interior fisheries in the world, the Mekong River fishery, includes it as one of its key fish species. Its prolific spawning behavior, which results in relatively large numbers of larvae that are easily harvested from flowing rivers, is probably where the traditional development of capture-based aquaculture for this species began, particularly in Vietnam and to a lesser extent in Thailand and Cambodia.

Due to its wonderful flavor and deliciousness with a high protein, mineral and fat contents in its meat, it makes a good fishery of substantial value and is utilized to fetch a high market price as a food fish. It is well-liked as a game fish as well. It recently entered the ornamental fish market and it has also been confirmed that India exports it as an indigenous ornamental fish.

Andhra Pradesh receives the most amount of seed exports, followed by the states of Bihar, Chhattisgarh, Kerala, Rajasthan, Uttar Pradesh, and Karnataka. With annual seed production capacity of 300 to 500 million tons, West Bengal state has emerged as a key location for *Pangasius* seed production in the nation. *Pangasius* seed production is not only offered for aquarium commerce but also for use in culture (Singh and Lakra, 2012).

*Pangasius* cultivation in ponds is known to produce between 7 and 50 tons per hectare per year (Griffiths *et al.*, 2010). The West Bengal fish seed industry was crucial in spurring the growth of Andhra Pradesh's *Pangasius* farming (Ali *et al.*, 2013). With the help of trans-border hatcheries, fish seed traffickers from West Bengal were able to meet Andhra Pradesh's demand for 2 billion *Pangasius* seeds (Tam *et al.*, 2010; Padiyar *et al.*, 2014). The second-most significant expense, which makes about 12–14% of the

total cost of production, is seed (Mugaonkar *et al.*, 2019). This is more expensive than what Bangladeshi farmers pay (Alam, 2011).

Pangasius seed may now be produced on a commercial scale through induced breeding, due to the establishment of hatcheries and seed production facilities for the species in Andhra Pradesh (ICAR, 2013). Following this, Andhra Pradesh's dependence on West Bengal was reduced to 30% in 2018 due to the creation of one significant commercial hatchery facility in the private sector.

The striped catfish, *Pangasianodon hypothalamus*, is well-known among hobbyist aquarists as the "Iridescent shark/Tiger Shark" in aquarium trade. Because they are hardy (Bailey, 2021; McGee, 2010), they have impressively been adopted as a commercial aquaculture species and contribute to 15-20% of the aquarium trade in Andhra Pradesh in addition to having export value as native ornamental fish (Gupta and Banerjee, 2012) Tiger sharks are not an easy fish to keep, though, according to aquarium owners, since the fish have a tendency to strike the aquarium wall blindly, which can cause injuries that cause the fish to drop to the bottom where they may remain until they recuperate or occasionally pass away (Axelord and Leonard, 1996).

Other huge fish like Arowanas, Datnioides, and giant Cichlids are some of the fish that *Pangasianodon hypothalamus* gets along with in a tank (Bailey, 2021; Seshagiri *et al* 2013). The main factors affecting the production of Pangasius are feed, seed, farm size, labor, land leasing and days of culture. Compared to small and marginal farms, the cost of production in Pangasius farming is 20% greater in large farms (Mugaonkar *et al.*, 2019). Feed makes up 80–85% of farmers overall production costs (Alam, 2011; Nguyen, 2013). Feed is followed by seed, which is the second-most significant expense and accounts for 6-8% of cultivation costs, but Mugaonkar *et al.* 2019 indicated that seed costs make up 12–14% of production costs.

On average, the cost of occasional human labor makes up between two and three percent of all variable costs. In contrast to a 4% increase in fish production, an extension of the culture time causes a 10% rise in production costs. (Alam, 2011; Seshagiri *et al* 2013).

With a production rate of 35 tons per hectare, the average cost of producing pangasius in Andhra Pradesh is INR 65–70 per kilogram. Since the start of the culture in 2004, the cost of producing pangasius has climbed by 190% in India. Except for the

great irregularity in delivering remunerative pricing, farm-gate prices climbed by 180% by 2020. Profits in *Pangasius* culture have decreased concurrently from 54% in 2004 to 18% in 2019. 9% of farmers have lost money because to the COVID pandemic, which is exceptional.

Due to the farmers strategic stocking and harvesting practices that they established in accordance with market trends, *Pangasius* farming in Andhra Pradesh is being sustained despite the extremely volatile markets in India (Mohan *et al.*, 2019) and other countries (Thong *et al.*, 2020; Seshagiri *et al* 2013).

One of the key elements affecting fish output and financial success in aquaculture methods is stocking density. Fish welfare may be lowered by persistent stress brought on by high stocking density (North *et al.*, 2006; Lupatsch *et al.*, 2010). The impact of stocking density on an ability of fish to develop and respond physiologically can vary based on several variables, including the fish's species, size, age and conditions during rearing, among others.

#### **Recirculatory Aquaculture System (RAS):**

Recirculatory Aquaculture Systems (RASs) are land-based aquatic systems that partially or entirely reuse water following mechanical and biological treatment to decrease water use, energy use and nutrient release into the environment, thus preventing eutrophication. When water is scarce, RAS system is a method for intensive fish production. Using a variety of components, the RAS system enables recycling of 90 to 99 percent of the water. RASs enable the best circumstances for fish production by giving the operator better control over environmental and water quality factors. (Heinen *et al.*, 1996).

For aquatic creatures to attain high levels of survival, development and reproduction, water quality is crucial. The relationship between aquatic production and water quality is crucial for the best possible development and survival of desired species. Extensive aquaculture may result in the overuse of groundwater, which might result in groundwater depletion, as well as other issues such the conversion of agricultural area into aquaculture land, which would have a detrimental effect on the output of agriculture. Better management strategies for fish production are thus required, and novel culture techniques with minimal water requirements must be implemented.

A recirculating system also has a lot of issues, including low water temperature, low dissolved oxygen, high concentrations of waste metabolites, etc. High or low water temperatures, low DO levels, gas supersaturation, detectable amounts of dissolved ozone, higher waste metabolite concentrations and the presence of specific cleaning agents or chemotherapeutants in the water can all contribute to the most prevalent water quality issues in RAS. (Twarowska *et al.* 1997).

Physical and chemical characteristics of water have a significant role in its quality, which in turn influences how well it supports the growth and dispersion of fish and other aquatic life (Toma, 2011).

Nitrate concentrations, pH and alkalinity make up crucial water quality indicators in a recirculating culture system (Cristea *et al.*, 2002). It is well known that the bearing capacity, also known as the carrying capacity, of semi- and intensive aquaculture recirculating systems is devastatingly dependent on its design, technology, and operational management. Therefore, removing a lot of metabolic waste is necessary for high density stocking (Bhakta *et al.*, 2009). It is well acknowledged that understanding the proper stocking density is crucial because it has a significant impact on improving fish output to meet the ongoing rise in fish demand and maintain a productive and economically viable culture system for fish farmers (Rafatnezhad *et al.*, 2008). The term "stocking density" (Ellis, 2001) refers to the weight of fish per unit volume or the quantity of fish supplied at the start of an experiment (Ruane *et al.*, 2002). Fish that are stocked in large numbers frequently display aggressive behavior, especially when food is scarce. This situation frequently causes fish stress, which might have an impact on the health of the fish. Therefore, when considering fish density, food availability is crucial (Holm *et al.*, 1990).

The RAS may be used as hatcheries to generate spawn, fry and fingerling fish for stocking as well as decorative fish for home aquariums or as grow-out systems to create food fish (Helfrich & Libey, 1991). RAS provides more independence from the outside environment (i.e., higher degrees of control) in comparison to conventional aquaculture approaches, providing a foundation for improved risk management (Rawlinson, 2002).

By using precise stocking density, improved development and survival and the usual physicochemical properties of water, this research may enable fish farmers to boost fish productivity. The degree of sustainability of agricultural systems in the future with the following research goals will be crucial for maintaining the world population's growth and development within the safe bounds of the planetary boundaries-

1. To study the growth performance of *Pangasius pangasius* in relation to different stocking densities in different locations at Commercial Recirculatory Aquaculture System (RAS).
2. To Study the certain water quality parameters of *RAS* system.
3. To study the economics of fish production in *RAS* systems.

## 2. REVIEW OF LITERATURE

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Over the past two decades, there has been a significant surge in research on the creation of RAS for commercial scale fish production (Masser *et al.*, 1999). Research had been done on the creation of unit processes and their incorporation into useful water-reuse systems (Timmons *et al.*, 2002). The ultimate objective of these research initiatives was to increase the cost-effectiveness of finfish production in recirculating systems. Due to the growing human population, there is a significant demand for fish in the market. Therefore, it is necessary to improve fish output using a variety of high-tech aquaculture techniques, such as fish farming in raceways and recirculatory systems. The current study on fish farming in recirculating aquaculture systems has been chosen to assess the fish output in it, in the light of the aforementioned facts.

Losordo and Westerman (1994) explained about the cost of generating a kilogram fish in the recirculating system described was estimated to be \$2.79 (\$1.27/Lb.) in an economic analysis of tilapia production in a small recirculating production system at a demonstration facility at North Carolina State University. The findings showed that while increases in the performance effectiveness of system components did not significantly affect variables like the costs associated with fish production, decreases in feed costs and improvements in the feed conversion ratio caused the biggest drops in operational structure production costs.

Kazmierczak *et al.* (1995) explained to create a bioeconomic model of fish development in recirculating aquaculture systems, metabolic sub-models for growth, ammonia generation and oxygen consumption. Results show that these linkages' economic significance varies over time in response to fish weight and not necessarily in the manner that their physical significance would imply. Particularly, across relatively constrained areas of management capability, tradeoffs between dietary protein and stocking density are economically viable. The biological reality of recirculating systems may prevent lucrative system operation in the absence of highly skilled and effective management.

Singh *et al* (1998) observed the Total organic carbon (TOC) content and biochemical oxygen demand (BOD) of the systems, as well as statistical comparisons of various water quality features and their impacts on water exchange. Comparatively two systems with bead biofilters and the systems with trickling biofilters showed lower levels of total ammonia nitrogen (TAN), nitrite-nitrogen (NO<sub>2</sub> -N), and TOC in the tank water. In comparison to systems with settling basins, screen type particle filter systems used less make-up water.

Ridha and cruz (2000) observed the efficiency of the media's quality criteria, which were good at eliminating harmful ammonia and at keeping levels within the permissible and safe ranges for growth and survival. As a result, using plastic chips would be more cost-effective due to their lower prices. Daily growth rates (1.17 and 1.18 g/fish per day), FCR (2.04 and 1.98), and survival rates (97.6 and 98.2%, respectively) did not differ significantly ( $P>0.05$ ) between the chip and block media. Using a filter medium capacity of 1.0 m<sup>3</sup>, it is able to produce 215.0 kg of tilapia on average.

Shnel *et al.* (2002) studied a 331-day grow-out time and a zero-discharge recirculating system, tilapia was grown from fingerling size to market size. Maximum stocking densities of 61.8 kg/m<sup>3</sup> resulted in an overall output of tilapia biomass during the grow-out phase of 81.1 kg/m<sup>3</sup>. The concentrations of inorganic nitrogen were suitable for culture.

Wik and Linden (2004) described about the Recirculating Aquaculture Systems (RASs), which biologically cleanse fish tank effluent before cycling it back to the tanks, present a potential for ecologically sustainable fish production. However, given the complexity of Recirculating Aquaculture Systems, study and optimization of a plant with regard to setup, effluent water quality, productivity and resilience needed dynamic simulations.

Colt (2006) described about the temperature, dissolved oxygen, total gas pressure, ammonia and nitrite which are examples of water quality requirements for aquaculture systems. For a single species and life stage, these requirements might not be suitable, especially for commercial purposes. Many variables, including fine particles, refractory organics, surface-active chemicals, metals, and nitrate, may become significant in water reuse systems. As a result, the limiting considerations in

systems with very high intensity reuse are still not well understood. Production-scale tests are necessary for the development of more pertinent water quality standards for reuse systems.

Ali *et al.* (2006) demonstrated a commercial fish production using water recycling technology which was started in the spring of 1998 at Banha University Faculty of Agriculture Agricultural Engineering Department. The system was planned to be 32.0 m long by 12.0 m broad. It is intended to produce 30 tons of fish each year, with tilapia as the first crop.

Akinwale and Faturoti (2007) conducted research on the biological performance of African catfish (*Clarias gariepinus*) in industrial recirculating systems in Ibadan, Nigeria. The water temperature measured in rearing tanks varied from 22 to 28<sup>0</sup>C in grow-out rearing tanks, 23 to 26<sup>0</sup>C in juvenile systems, and 23 to 25<sup>0</sup>C in fingerlings systems. In grow-out systems, DO levels decreased to as low as 2.0 mg/l while SS levels increased to as high as 36 mg/l.

Stocking densities ranged from 20,000 to 31,000, 6000 to 9000 and 150 to 300 fish/m<sup>3</sup>, while survival rates for fingerlings range from 75 to 80%, juveniles from 75 to 93% and adults from 77-88%. Feed conversion ratios for fingerlings and juveniles varied from 0.60 to 0.78 and 1.02 to 2.08, respectively. Mean harvest weights for fingerling, juvenile and adult fish, respectively, were 4.2, 11.2 and 981.0 g, raised on average for 28, 30, and 154 days, respectively.

Bijo (2007) conducted research on the findings of raising Arctic charr (*Salvelinus alpinus*) to test the technical operation of the systems showed that both could eliminate carbon dioxide to levels suitable for fish development and giving enough dissolved oxygen. Both systems could potentially give the best water quality for fish development in the cold-water habitat at the site. A scale-up system for cultivating seabass (*Lates calcarifer*) in Malaysia is financially possible, but it is susceptible to changes in price, operating expenses, and output volume. This is demonstrated through commercial simulation. Starting a RAS farm is difficult since it requires coordinating the use of expertise in aquaculture engineering, water quality management and financial responsibility before profits can be generated.

Martins *et al.* (2010) stated that it is possible to distinguish between flow through ( $>50 \text{ m}^3/\text{kg}$  feed), reuse ( $1\text{--}50 \text{ m}^3/\text{kg}$  feed), conformist recirculation ( $0.1\text{--}1 \text{ m}^3/\text{kg}$  feed), and "next generation" or "innovation" RAS ( $0.1 \text{ m}^3/\text{kg}$  feed) based on system water exchange.

Enache *et al.* (2010) presented paper on some aspects regarding the impact of stocking density on common carp breeding in a closed-loop aquaculture system (RAS). It was carried out in four 500 L-capacity aquaculture tanks as part of the "Dunarea de Jos" University of Galați Recirculating Aquaculture pilot system. Following information was derived from the technical indicators: The food conversion ratio (FCR), calculated as the mean value of the two repetitions, was 1.28 in V1 and 1.06 in V2, indicating a higher efficiency in capitalizing food in V2. The specific growth rate (SGR), calculated as a mean value on the two repetitions, was 1.28%/day in V1 and 1.49%/day in V2, indicating better growth in V2. Due to the high stocking density, the breeding units' effluent removes a significant quantity of metabolic waste.

Alam (2011) conducted study to Analyze the technical (TE), allocative (AE), and cost-effectiveness (CE) of Bangladeshi farmers who produce Pangas ash. Production of Pangas is characterized by significant technical, allocative and financial inefficiency. Important efficiency factors include pond size, fingerling size, culture length and usage of pelleted feed. In terms of the benefit-cost ratio, break-even yield, and price criterion, it is still profitable. Eliminating inefficiencies will increase the profitability of Pangas production. Given their pricing, the right input blending might help Pangas producers optimize their profits. It was anticipated that efficiency improvements would aid in raising output and open up opportunities for exporting the surplus. To boost productivity and develop pangas culture, more fisheries extension was recommended.

Zhang *et al.* (2011) explained about the fish output was correlated with changes in water quality as measured by culture efficacy (final weight, survival rate, SGR and yield). In contrast to filter-feeding fish, the three primary species used for rearing showed a declining tendency along the flow direction that was greater than the control. The described cultivation approach would be more suited for species that are sensitive to water quality in typical subtropical settings since RAS may provide improved environmental conditions year-round.

Kubi (2012) conducted an analysis of the economics of producing Tilapia in a Recirculating Aquaculture System at the Norwegian University of Life Sciences (UMB). The objectives were to: (1) assess and estimate the operational costs involved and from there, determine the break-even cost; (2) identify and describe the RAS-specific constraints; (3) determine the financial viability of a (supposed) scale-up production; and (4) perform sensitivity analyses on a few variables to show how their effects on profitability. The technical design and production characteristics present at the UMB plant served as the basis for all assumptions made in this study, the production scale and the economic analysis. The tanks were filled with Tilapia (0.36g), which were meticulously monitored for temperature and water quality until the fish reached harvestable size (700g) after 140 days. The feed conversion ratio (FCR) and survival rate were 91% and 0.8, respectively. In order to break even in this case, output would have to be boosted by 54.8%. The second analysis operating cost was significantly reduced because of including cost information from commercial productions. Reductions in the cost of production factors including labor, feed and power have only slight influence on profitability, according to the sensitivity analysis. The most significant effects on profitability were determined and found increase in sales price and production size and improvements in both factors would result in the largest profits.

Badiola *et al.* (2012) analyzed that the key problems for Recirculating Aquaculture Systems (RAS) are to identify potential areas for improvement, future obstacles for the sector and improved solutions for future management. Separate interviews with RAS-based production businesses, researchers, system providers and consultants were conducted in order to get a general grasp of such systems and learn about potential future advances. The producers limited engagement, a disincentive to share knowledge and a lack of communication between various stakeholders were highlighted by the answers and later analysis as significant impediments. The primary problems are the systems bad designs, since many of them had been altered after an earlier strategy proved ineffective and their poor administration, mostly because there are not enough qualified individuals in charge of things like water quality.

Ali (2012) analyzed that Banha University Agriculture College is home to a technological and financial facility for Tilapia production employing a Recirculating Aquaculture method. The tanks were filled with Tilapia (1.0g), which were carefully

monitored for temperature and water quality until the fish reached harvestable size (500g) after 180 days. The feed conversion ratio (FCR) and survival rate were 1.5 and 90%, respectively. The findings demonstrated that the operating costs associated with system manufacturing were appropriate and economically sound.

Mota *et al.* (2015) explained about the risk that fish in RAS may grow less than in flow-through systems owing to the buildup of chemicals from feed, fish or bacteria connected with the water re-use is a difficulty that Recirculating Aquaculture Systems (RAS) are presently addressing. This study looked at how feed intake and growth of African catfish *Clarias gariepinus*, European eel *Anguilla Anguilla*, and Nile tilapia *Oreochromis niloticus* were affected by RAS with high and low accumulation levels of these chemicals. Twenty-one hundred members of each species were employed (initial body weights: European eel 66.6 1.3 g, African catfish 253.2 2.1 g, and Nile tilapia 264.8 8.3 g). Growth and feed consumption were examined over a 39-day period comparing animals with high and low accumulation RAS. High augmentation RAS was built to: (1) operate at nearly-closed circumstances (30 L/kg feed/d), employing mature biofilters and high feed loads, for maximum accumulation of chemicals in the water; and (2) minimize accumulation. By operating at high water exchange rates (1500 L/kg feed/d), innovative biofilters and low feed load, RAS was created to be a stand-in for flow-through systems. In comparison to systems that provide a proxy for flow-through conditions, High accumulation RAS caused a decrease in feed intake (42%) and growth (83%) in Nile tilapia.

Rurangwa *et al.* (2015) stated that Recirculation aquaculture systems (RASs) are being viewed more and more as the production methods of the future for producing aquatic food with the least amount of ecological damage. The systems depend on a varied microbial population active in various processes of water purification as well as undesirable impacts in order to maintain good water quality and to generate high-quality and healthy fisheries products.

Brandli (2015) conducted research to study the TBL of a RAS responded favorably to the impacts of venturi/vortex components in a RAS for oxygen augmentation. Utilizing venturi and vortex elements, off-gasses were evacuated while also increasing the amount of dissolved oxygen in the solution. The venturi/vortex devices were driven by a solitary water pump. Dissolved oxygen concentrations should be less than 5 mg/L for the best plant and fish development. Actual stocking densities

exceeded early forecasts of stocking densities by 144% and the 42-day trials dissolved oxygen level was 56.86% over the minimum necessary level of 5 mg/L. In reality, this might be a more environmentally friendly RAS approach that complies to the triple bottom line (TBL) of social justice, economic viability and environmental stewardship.

Ngoc *et al.* (2016) stated about the adoption of RAS, which necessitates very big initial expenditures, is heavily dependent on how economically viable Vietnamese agriculture is. The latter contains the sociodemographic traits of the farmers in addition to economic considerations. In order to determine farmers' preferences for RAS in pangasius production in Vietnam, this study conducted a choice experiment. A farm's location also matters; for example, farmers in saltwater intrusion zones are more likely to use RAS than those in freshwater areas. Age, education, gender and household income are other factors that are strongly linked to the likelihood of adopting RAS. Relevance statement: Implementing Recirculating Aquaculture Systems is seen to be a crucial step in ensuring Pangasius farming complies with sustainability certifications and disease management.

Ngoc *et al.* (2016) analyzed the Recirculating Aquaculture Systems (RAS) which are economically viable for Pangasius production in Vietnam. Data were collected throughout the Mekong River Delta through workshops and structured questionnaires. Results indicated that after installing RAS, net present value for big farms increased from an average of 589,000 USD/ha to 916,000 USD/ha. Overall, they concluded that for both farm sizes, the chance of RAS being a beneficial investment is determined to be 99%. Prices, yield, fingerling cost, feed cost and initial investment are the main factors that influence profitability using RAS. The results of the RAS's economic analysis are deemed helpful for assisting both public and private decision-making in order to increase the sustainability of Pangasius production.

Gupta (2016) stated that the several countries, including India, Bangladesh, Pakistan, Myanmar, the Malayan Peninsula, Indonesia, Vietnam, Java, and Thailand, are home to the catfish species *Pangasius pangasius*. It is a well-liked eating fish with a high concentration of protein, minerals and fat in the flesh. It is also a well-liked game fish, and it has just begun to appear in markets for ornamental fish. Although *Pangasius pangasius* is naturally hardy, with a high tolerance for temperature, salinity and turbidity, natural populations of this fish species are in danger of going extinct due to

overfishing, habitat degradation, water pollution, destruction of the breeding grounds, etc. It is now imperative to take serious action to preserve its natural population.

**Palm et al. (2018)** researched on African catfish (*Clarias gariepinus* Burchell, 1822) which were raised in commercial warm water Recirculation Aquaculture Systems (RAS) at three different stocking densities: extensive (maximum 50 kg m<sup>3</sup>; 35 fish tanks), semi-intensive (maximum 100 kg m<sup>3</sup>; 70 fish tanks), and intensive (maximum 200 kg m<sup>3</sup>; 140 fish tanks) all at roughly equivalent system volumes of 13.9, 15.1 and 16.9 m<sup>3</sup>. Dissolved nutrient concentrations were affected by maintenance intervals, feed ratios and oxygen levels, with the highest concentrations occurring under intensive stocking density, medium feed input and oxygen > 6 mg/l, and the lowest occurring under semi-intensive stocking density, high feed input and oxygen > 6 mg/l.

Strauch et al. (2018) explained about a fuller comprehension of the material routes, nutrient and energy fluxes and effluent water and sediment reuse for African catfish (*Clarias gariepinus*) recirculation aquaculture systems is necessary. 58.3-64.2% of the phosphorus from the feed was found in the fish, 9.7-19.3% was found in the sediments and tiny quantities (9.6-15.5%) was found in the process fluids. A total of 7.1-9.9% of the feed accumulated as dry matter in the sediments, which included 3.7-5.2% nitrogen and 5.5-8.7% total organic carbon. Fish contained 44.5-47.1% of the feed energy and sediments held 5.7-7.7% of it.

**Shafiullah et al. (2018)** conducted experiment to find out the appropriate combination of indigenous carps and Thai Pangas (*Pangasius hypothalamus*) for polyculture in respect to growth, survival and production in different farmers ponds under semi-intensive rearing system. Supplemental feed containing 27.96% crude protein was provided only for Pangas at the rate of 8% of their body weight. Feed was supplied in the form of dough twice a day and no feeding tray was used. The average final weight gain of Pangas in all the treatments was higher than any other species. The average highest final weight gain of Pangas (340.10g) was recorded in T2 and lowest in T3 (318.19 g). On the other hand, average highest final weight gain of rohu, catla, and mrigal were found in T1 (250.28, 324.19 and 290.70 g) and lowest in T3 (200.37, 271.59 and 226.53 g). The mean survival rate of Pangas varied from 93.36% to 95.17% and for carps 89.00% to 91.07%. The significantly highest total production of fishes was 2627.48 kg/acre/3 months recorded in T1 which was followed by T2 (2553.77 kg/acre/3 months) and T3 (2448.41 kg/acre/3 months) respectively. The FCR values

were 1.23, 1.26 and 1.20 for the T1, T2 and T3, respectively. After the economic analysis it has been found the higher net return was (96,337.75 TK/acre/3 months) obtained in T1. So, it can be concluded that species T1 (rohu: catla: mrigal: pangas = 35:17.5:17.5:30) is the best species combination for carp and pangas polyculture.

Rafaey *et al.* (2018) investigated the effect of different stocking densities on growth, feed efficiency, blood biochemistry, histometric response, muscular composition and flesh quality of channel catfish *Ictalurus punctatus*. Fish were cultured at low, medium and high stocking density of 50, 150 and 300 fish m<sup>3</sup>, respectively, for 60 days in the recirculating aquaculture system. Fish growth and feed efficiency significantly decreased with increasing stocking density. Serum concentrations of glucose, triglyceride and total cholesterol, as well as the activities of both aspartate aminotransferase and alanine aminotransferase, significantly elevated as stocking density increased. High stocking density led to the decline in serum levels of thyroid hormones. The villi length and its number, as well as the size of goblet cells in the intestine, were negatively affected by high stocking density. There was a significant density-dependent decrease in muscular fat content, diameter of dorsal muscle fiber, intensity of muscular bundles and percentage of muscular bundles area in dorsal muscle. However, the percentage of the intramuscular connective tissue showed a significant increase in fish reared at high stocking density. Fish stocked in high density exhibited the decrease in muscle pH, drip loss and frozen leakage rate. Overall, the increased stocking density could cause the unfavorable impacts on growth, feed efficiency, histological change, and flesh quality of *I. punctatus*.

Mohammad *et al.* (2018) conducted economic analysis of a goldfish (*Carassius auratus* Linn.) Recirculating Aquaculture System (RAS) with rearing tank capacity of 5 m<sup>3</sup> (RT5) has been evaluated based on two culture period in 2009 and 2010. The stocking density of goldfish was kept at 100 numbers per m<sup>3</sup> of rearing water volume. Furthermore, based on the data obtained from RT5, four more hypothetical RASs of rearing tank capacities of 10 m<sup>3</sup> (RT10), 20 m<sup>3</sup> (RT20), 50 m<sup>3</sup> (RT50) and 100 m<sup>3</sup> (RT100) were conceptualized for economic analysis that assess and compare the effects of economies of scale on profitability. The payback period, accounting rate of return (ARR), net present value (NPV), profitability index (PI) and modified internal rate of return (MIRR) were evaluated for the different water volumes (up to 100 m<sup>3</sup>) assuming project life to be 10 years. The economic analysis revealed that a goldfish RAS with

rearing tank capacity 20 m<sup>3</sup> onwards can be feasible with a payback period less than 4 years, accounting rate of return 54%, net present value of Rs 241820 and modified internal rate of return of 23%.

Sites (2020) conducted research to evaluate two popular aquaculture species, tilapia (*Oreochromis niloticus*) and rainbow trout (*Oncorhynchus mykiss*), which were used to provide plant-available nutrients in three replicate recirculating aquaculture systems (RAS), which were created and run under pilot-scale production conditions. The second nutrient mass balance experiment evaluating nutrient production from rainbow trout in RAS employed tight sampling protocols in order to circumvent the challenges associated with correctly quantifying nutrient output from tilapia RAS. These tests produced results that were contrary to prior research and these discrepancies were most likely brought about by variations in experimental design, system design, feed, fish species and dilution effects.

Ahmad and Turchini (2021) stated RAS are with no negative environmental effects like habitat destruction, water pollution and eutrophication, biotic depletion, ecological effects on biodiversity due to captive fish and exotic species escaping, disease outbreaks and parasite transmission. Indeed, these are Environmentally friendly, water-efficient, highly productive intensive farming systems. Additionally, because RAS functioned in a regulated indoor environment, climatic variables including changing rainfall, flooding, droughts, global warming, cyclones, salinity fluctuations, ocean acidification, and sea level rise had no impact on it. Despite these opportunities and promises, RAS hasn't been extensively used, especially in poor nations, because of the complicated and expensive system designs. To build low-cost, energy-efficient RAS for raising fish output, lowering GHG emissions and coping with climate change, more study and technology advancements are required.

Wenzel *et al.* (2021) investigated the juvenile African catfish (*Clarias gariepinus*) treated with four concentrations of K (K0 = 2, K200 = 218, K400 = 418, and K600 = 671 mg/l) in terms of growth, feed conversion, body composition, and welfare parameters. While growth, feed conversion and ultimate body composition were constant, an increase in K<sup>+</sup> resulted in considerably longer feeding times and more individual resting. This made it possible to use KOH in RAS to supply alkalinity to achieve optimal nitrification at the lowest possible water exchange and improve the

nutritional profile of the process water, which had positive effects on the welfare status of African catfish and the production, and quality of aquaponics plants.

Oktavia *et al.* (2021) study aimed to examine the effects of various filter media compositions on the survival and water quality of *Pangasius* sp. raised in the RAS test fish, with an average weight of 4.59 g and a density of 1.15 gL<sup>-1</sup> for 30 days. The two-times-daily feed supplied at satiation. There were four replications and five treatments used in the study. The composition of various filter materials had a significant (P0.05) impact on the Feed Conversion Efficiency (FCE), Relative Growth Rate, total amount of feed fed, and Survival Rate (SR). On RAS, different net and zeolite compositions were employed as filter media and were successful in lowering TAN below the tolerance level.

Idoko (2021) reviewed about the benefits of a system built for efficient water re-use with ideal water quality, for intense fish production and the reality of water recirculation in aquaculture practice. This cutting-edge method of sufficient water reuse demonstrates its applicability by enabling intensive fish production, conservation of available water, conservation of available space, ease of site location, flexibility to locate production facilities close to large markets, quick and effective disease control, complete and convenient harvesting, species and harvest diversity, particularly in areas where available water for culture purposes is limited. Recirculating aquaculture systems should thus be promoted as an optional technology for aquaculture.

Lopes *et al.* (2021) stated that in several related characteristics, including temperature, salinity, ammonia, hydrogen potential, nitrogen dioxide, bromine, and others, must be monitored for the aquaculture business to become more profitable and sustainable. They hoped that their ongoing, simultaneous monitoring would enable them to anticipate and avert catastrophes like unusually high rates of fish death. For the early prediction of high fish mortality, they provided a novel anomaly detection method in this study that is based on a multivariate Gaussian probability model. This method's objective was to establish a correlation between fish mortality and the number of daily registered physicochemical parameters in fish tank water. This method is appropriate for real-time tracking and accurate prediction of up to 80% of high fish mortality rates.

Indriastuti *et al.* (2022) studied effects of RAS-incorporated nursery culture on juvenile catfish survival rate (SR), specific growth rate (SGR), relative length (LR),

weight gain (WG), length gain (LG) and feed efficiency (FUE). The SR did not substantially change across treatments as a consequence. SGR, LR, WG, LG, and FUE values were greatest for the R4000 therapy ( $p < 0.05$ ). Total ammonia nitrogen and other water quality indicators, in particular, were lower in the RAS treatment than in the control.

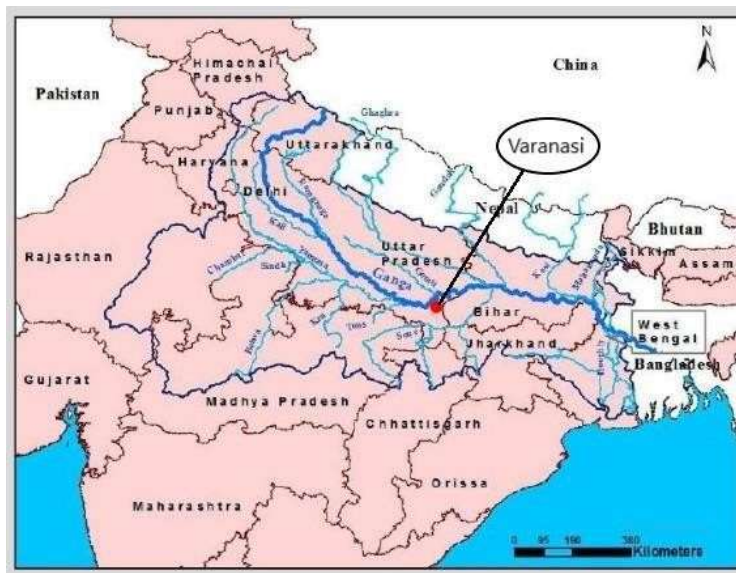
### 3. MATERIAL AND METHODS

The goal of the current study was to compare the growth performance of *Pangasius pangasius* in commercial recirculatory aquaculture systems at various sites in Varanasi (Uttar Pradesh), in order to determine the effects of various stocking densities on the growth parameters and water quality parameters of fish as well as the system economic analysis of RAS. A description of material and methods which were followed for conducting study is given below:

#### 3.1 STUDY AREA

In the eastern part of the state of Uttar Pradesh, at an elevation of 80.71 meters, in the heart of the Ganges valley in North India, Varanasi is located along the left crescent-shaped bank of the Ganges, between 15 and 21 meters raised above the river bed. Varanasi is 797 kilometers to the south-east of New Delhi, Lucknow is 320 kilometers, Allahabad is 121 kilometers, and Jaunpur is 63 kilometers away. Between 25° 14' and 25° 23.5'N and 82° 56' and 83° 03'E is the urban agglomeration is situated. The district has a total area of 1535 km<sup>2</sup>. The soil is incredibly fertile in North India's Indo-Gangetic Plains because to low-level Ganges floods.

**Fig 3.1-Map showing Varanasi district**



(Courtesy:<https://www.varanasihamstp.in>)

### **3.1.1 Geo-Climatic Features**

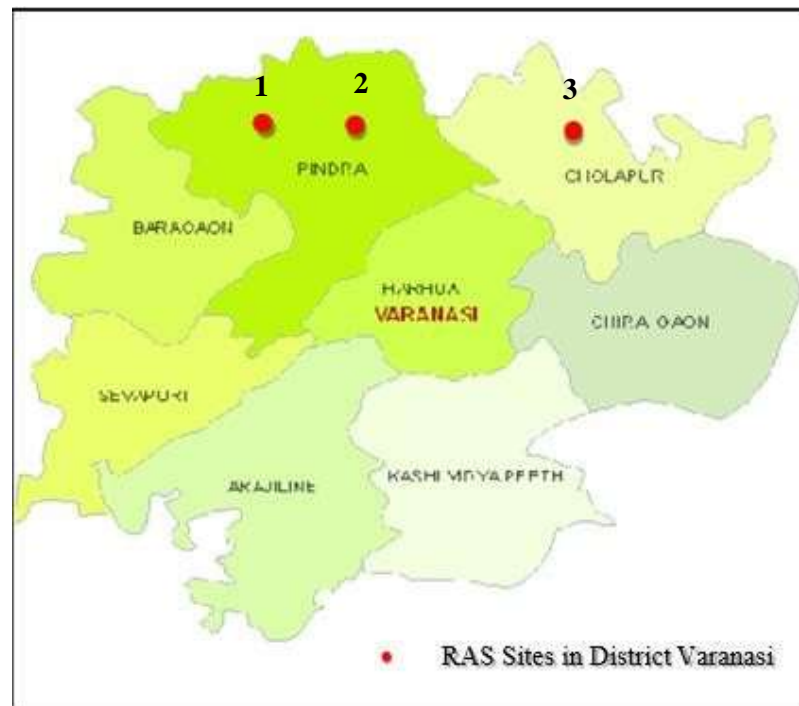
The agro-climatic conditions that may be distinguished from one another by the soil and topography found in the eastern plain zone are described below. Kinds of soil Sand, sandy loam, clay loam, sodic or saline soil Holding Size - Landless farmers, tiny and marginal farmers and having Canal and tube well irrigation facilities. Major A type of soil is one that is also referred to as deep red sandy loam soils. They are as follows in terms of area: clay loam 24.75%, sandy loam 46.25% and loam 16.37%. Varanasi's proximity to the Tropic of Cancer causes summer time temperatures to occasionally soar to 45 °C while also being humid. For about two months, the monsoon season, which normally begins in late June or early July, is characterized by heavy rain and high humidity. April marks the beginning of the dry summer, which lasts through June. The monsoon season follows from July to October. The summer time temperature is between 22 and 46 °C.

The winters in Varanasi, however, are pleasant, with lows of just about 7°C. In particular, the spring, when temperatures are moderate, is the greatest season to go between October and April. Varanasi's monsoon season often begins in late June. June through September sees the lion's share of the region's annual rainfall, which ranges from 680 mm to 1,500 mm. The average annual rainfall is 1,110 mm. The monsoon season, which lasts from June to October, is when 80% of the rain falls. The parameters of the river's flow are significantly variable throughout the year due to large temporal variations in precipitation. In the next seven months from November to May, just 8% of the rain falls, with only around 5% falling in October.

### **3.1.2 Study Sites in Varanasi District**

Present study was conducted at three sites located in the district Varanasi, Uttar Pradesh

**Fig 3.2 Map showing Study sites**



- 1) Village Majhwa
- 2) Village Chuppepur
- 3) Village Khanuaan

### **3.1.3 Commercial RAS Systems**

There was total 8 cemented tanks in each site, size of each tank was 7.65 x 7.65 x 1.5 m. The unit comprises of the filtration tank as well. The water capacity was 1 lakh liter Filled with 58,000L. The water used in the tank is changed every day and sometimes twice a day.

### **3.2 ANALYTICAL METHODOLOGY FOR WATER QUALITY**

Different water quality parameters were analyzed following APHA (2017). During the study period for analysis methods of standard practices were followed to observe selected water quality parameters at fortnightly interval.

### **3.2.1 Water temperature**

The digital thermometer was directly submerged into the water to measure and record the water temperature. The air temperature was also monitored using this digital meter.

### **3.2.2 pH**

The difference in potentials of glass electrodes measured on a scale directly calibrated in pH units represents the activity of hydrogen ions in a solution pH was recorded with a typical digital pH meter.

### **3.2.3 Electrical Conductivity**

The ability of water to carry electric current is known as electrical conductivity. It is stated as mS/ cm. An EC meter of the pen type was used to measure this parameter.

### **3.2.4 Alkalinity**

Water alkalinity was estimated by titrating 50 ml of sample using sulfuric acid (0.02N) as titrant. The phenolphthalein alkalinity was estimated to be first end point (pH 8.3) by phenolphthalein indicator; bicarbonate alkalinity was measured to the second end point (pH 4.5) with methyl orange indicator. Following steps were used for alkalinity determination.

$$\text{Total alkalinity (mg/l)} = \frac{\text{ml of titrant}}{\text{ml of sample}} \times 1000$$

### **3.2.5 Dissolved oxygen**

Winkler's technique was used to measure the amount of dissolved oxygen in a water sample using Winkler A (manganous sulphate) and Winkler B. (Alkaline- iodide solution). Iodine equivalent to that of oxygen fixed is released when manganous hydroxide and oxygen react to generate higher hydroxides. Following this, a titration was performed using standard sodium thiosulphate solution and starch as an indicator.

**Following steps for estimating dissolved oxygen were taken:**

- I. A sample was taken in a 250 ml glass container without bubbling water.
- II. Using separate pipettes for each, 2 ml of Winkler A and Winkler B were poured into the sample vial one at a time. Use the stopper to cap the bottle.

- III. After shaking that bottle five times upside-down, a brown precipitate developed; this was then allowed to settle at the bottom.
- IV. 2 ml of concentrated H<sub>2</sub>SO<sub>4</sub> was used to dissolve the precipitates, and the bottle was shaken once more.
- V. Sodium thiosulphate (0.025 N) was titrated with a 50 ml aliquot of the entire sample in a flask until the color turned pale straw.
- VI. Two drops of starch indicator were then added and the dark blue-black hue at the end point was changed to colorless.
- VII. The reading was taken down and the following formula was employed to calculate further:

$$\text{Dissolved oxygen (mg L}^{-1}\text{)} = \left[ \frac{8 \times 1000 \times N}{V_1} \times V_2 \right]$$

Where,

N = Normality of the titrant (0.025 N),

V<sub>1</sub> = Volume of sample (ml),

V<sub>2</sub> = Volume of titrant used (ml)

### 3.3 GROWTH PARAMETERS:

Sampling was conducted in all the three units fortnightly to access the growth pattern of stocked fishes. Following observations were made-

1. Fish seeds were transported from West Bengal by the seed traders in the month of August, 2022
2. There were 3 site units having different stocking density as Site 1-86/ m<sup>3</sup>, Site 2-97/m<sup>3</sup> and site 3- 115/ m<sup>3</sup>. Fishes were fed at the rate of 6.5-8% body weight.
3. All the three units were having 8 tanks which were stocked at different stocking densities of fingerling per tank.

Three sites as- Site 1- Village Chuppepur

Site 2-Village Majhwa

Site 3-Village Khanuaan

4. Initially water exchange was done after the laps of 10 days. As the fishes grow this duration get reduced depending on the visual observation of water quality.
5. Farmers used Potassium permanganate (KMNO<sub>4</sub>) to clean the water. In case of increased ammonia, common salt of varying doses was also applied.
6. There was no outbreak of any major disease.
7. All units were using similar feed of ABIS brand.
8. Dose and application method were advised by the feed suppliers accordingly farmers followed the schedule.
9. Farmers usually run aerator for few hours depending on the availability of electricity supply.
10. Floating dead fishes are removed out by using hand net.
11. For initial few weeks farmers do not use any net for the sampling to avoid disturbance to fishes. After attaining strength occasionally, they observe physical health of the fishes, however, the scientific approach for such regular monitoring is missing.
12. It is observed that the growth rate among the all units were more or less similar.

During the experimentation, the fish growth parameters *i.e.*, weight gain (WG), specific growth rate (SGR) and feed conversion ratio (FCR) were monitored at 15 days interval. For calculating the growth parameters following formulae were used as given below:

Weight gain (g)

This is determined by considering both initial & final weight of the experimental fish.

$$\text{Weight gain (g)} = W_i (g) - W_o (g)$$

Where,

$W_i$  = Final weight of live fish (g)

$W_o$  = Initial weight of live fish (g)

### 3.3.1 Specific growth rate (SGR) percent

$$\text{SGR\%} = \frac{\text{Ln. final body weight} - \text{Ln. initial body weight}}{\text{Duration of feeding(days)}} \times 100$$

### **3.3.2 Feed conversion ratio (FCR)**

$$\text{Feed conversion ratio} = \frac{\text{Quantity of feed intake (g)}}{\text{Net weight gain (g)}}$$

### **3.4 ECONOMIC ANALYSIS:**

Economic analysis was done on the local market price in terms of the Indian rupee and following formulae were used:

$$\text{Per cent return to variable cost} = \frac{\text{Net profit}}{\text{Total variable cost}} \times 100$$

$$\text{Per cent profit to turnover} = \frac{\text{Net profit}}{\text{Total return}} \times 100$$

$$\text{Benefit cost ratio} = \frac{\text{Total return}}{\text{Total cost}}$$

### **3.5 STATISTICAL ANALYSIS**

The collected data including water quality parameters, growth parameters of fishes and graphical presentation were also prepared with the help of MS-Office excel 2010 and (SPSS version 16.0) and ANOVA, SE were calculated.



**Plate 1- Study site 1 (Village Majhwa)**



**Plate 2 - Study site 2 (Village Khanuaan)**



**Plate 3 - Site 3 (Village Chuppepur)**



**Plate 4- Analysis of water quality**



**Plate 5- Experimental fish**



**Plate 6 - Commercial feed (IB)**

## 4. EXPERIMENTAL RESULTS

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This chapter describes the results of studies in commercial Recirculatory Aquaculture System to assess the effect of stocking density on the growth performance of *Pangasius pangasius*. The results of the experiment with proper discussion are presented under the following points-

- 4.1 Physical characteristics of water
  - 4.1.1 Air temperature
  - 4.1.2 Water temperature
  - 4.1.3 Electrical conductivity
  - 4.1.4 Total dissolved solids
- 4.2 Chemical characteristics of water
  - 4.2.1 Dissolved oxygen
  - 4.2.2 pH
  - 4.2.3 Total alkalinity
- 4.3 Growth parameter
  - 4.3.1 Feed conversion ratio
  - 4.3.2 Specific growth rate
  - 4.3.3 Weight gain
  - 4.3.4 Survival rate
- 4.4 Economics of Recirculating Aquaculture System

### WATER QUALITY PARAMETERS

Physical and chemical characteristics of water have a significant role in its quality, which in turn influences how well it supports the growth and dispersion of fish and other aquatic life (Toma, 2011). In a Recirculating culture system, the concentration levels of several water quality factors, including temperature, pH, oxygen, TDS, alkalinity, etc., are significant. (Cristea *et al.*, 2002). All these aspects support the

employment of Recirculating Aquaculture Systems, which enable the growth of numerous, excellent fish in a restricted amount of water.

Standard methods of APHA (2017) were followed to test different water quality parameters like Temperature, Dissolved Oxygen, Alkalinity, TDS, Electric conductivity and pH.

## **4.1 PHYSICAL CHARACTERISTICS OF WATER**

### **4.1.1 Air Temperature**

During the study, the air temperature was recorded 22.6°-30.4° C with mean value 28.70 °C (Table 4.1).

### **4.1.2 Water Temperature**

The experiment started in early August and ended in mid-October. In the experiment bore well water was used as a source of water by farmers and its minimum temperature was 25.7 °C at site 1 and maximum 26.1 °C at site 3. (Table 4.1 and Fig. 4.1).

### **4.1.3 Electrical Conductivity**

The ability of water to conduct an electrical current due to the presence of ions in water is known as EC. Digital meter was used to determine the range of electrical conductivity. During the Study period the electrical conductivity was studied (Table 4.1 and Fig. 4.3). The mean value of conductivity was observed in a range of 0.63 to 0.65 mS/cm. The lowest value of conductivity was recorded at the Site 1 (0.63mS/cm) while the highest value was obtained at Site 3 (0.65 mS/cm).

### **4.1.4 Total dissolved Solids**

Total dissolved solids content has been used as a measure of aquatic environment productivity (Jhingran, 2006). During the Study period the TDS was studied (Table 4.1 and Fig. 4.6), the concentration of total dissolved solids ranged from 229.72 to 313.67 mg L<sup>-1</sup>.

## **4.2 CHEMICAL CHARACTERISTICS OF WATER**

### **4.2.1 Dissolved oxygen**

The most crucial aspect of water quality for fish production is dissolved oxygen. Fluctuations in DO were noticed in the range of 6.22 to 7.15 mg/l (Table 4.1 and Fig.

4.4). The lowest dissolved oxygen was observed in 6.22mg/l at Site 1 and the highest dissolved oxygen was observed at Site 3 which was 7.15 mg/l.

#### **4.2.2 pH**

The pH of water shows how it is acidic or basic. Aquatic systems' pH levels are a result of a combination of several environmental factors. During the present study, pH ranged from 7.3 to 7.8 in different Units (Table 4.1 and Fig 4.2).

#### **4.2.3 Total Alkalinity**

In the present study, the average alkalinity was found in between the range of 136.3 (Site 1) to 142.9 (Site 3) mg/l. (Table 4.1 & Fig 4.5).

### **4.3 GROWTH PARAMETERS**

Growth performance of fish studied in culture period in different units was studied and summarized in Table 4.6. Following observations were made-

#### **4.3.1 Net Weight gain**

During the period of study, the total net weight gain in Site 1- 111.16±0.59 gm, Site 2-72.91±0.14 gm and Site 3- 57.93±0.55 gm (Table 4.2 & Fig 4.8). The total net weight gain of all sites was significantly different (CD=0.45) during research duration. The percentage weight gain of all the three units was different. Weight gain (%) is shown in decreasing order in the following manner: 95.25 (Site 1) > 90.73 (Site 2) > 82.73 (Site 3) (Table 4.3 & Fig 4.7). The Percent weight gain of all Study units was significantly different (CD=4.76) during study duration.

#### **4.3.2 Feed Conversion Ratio**

The results on FCR for different sites groups have been summarized in table 4.5 and the graphical representation is shown in Fig 4.10. The result revealed that the best FCR was recorded for Site 2 (1.35) fishes followed by Site 1 (1.55) and Site 3 (1.74). FCR was also found significantly different (CD=0.14) among all study sites.

#### **4.3.3 Specific growth rate (SGR)**

The significantly higher growth rate and specific growth rate indicate the effective role of feed in the growth performance. Results were found significantly different (CD=0.19). The results on SGR in different sites groups have been summarized in Table 4.4 and also the graphical representation is shown in Fig 4.9. The

result revealed that the best SGR was recorded for Site 1 (4.2%), followed by Site 2 (4.1%) and Site 3 (3.7%) after 60 days which was statistically non-significant to each other at 5% level of significance.

#### **4.3.4 Survival rate**

There was different survival rate of different study unit site 1- 93.75%, Site 2- 94.33% and site 3- 88.18% was observed during the study period.

#### **4.4 ECONOMICS ANALYSIS**

The expenditure in variable cost includes fish seed, fish feed and miscellaneous expenditure (water charges, electricity, filter bed pump, etc.) The miscellaneous/Labor expenditure varied in site 1-2500, site 2-2700 and site 3-2900. The total variable cost based on cubic meter area in different RAS in units was site 1-59990, site 2-35631 and site 3-46136 rupees (₹) respectively. (Table 4.7)

The production in different RAS units was site 1-548.66, site 2-415.99 and site 3-386.08 kg/m<sup>3</sup> respectively. The net profit obtained different RAS units was site 1- 8592, site 2-16367 and site 3-4734 rupee (₹) respectively. A better percent return to variable cost and percent return to turn over was found at site 2 of RAS. Benefit cost ratio for different RAS units was site 1-1.14, site 2-1.45 and site 3-1.04, respectively.

**Table 4.1: Ranges of Fortnightly water quality parameters. In parentheses mean values during the experimental period in different Sites are shown**

<b>Parameters</b>	<b>Site 1</b>	<b>Site 2</b>	<b>Site 3</b>
<b>Air temp. (°C)</b>	(22.6-30.4) (28.70)		
<b>Water temp. (°C)</b>	(24.90-26.10) 25.72	(24.98-26.40) 25.64	(24.70-26.50) 26.16
<b>Electrical conductivity (mS/cm<sup>-1</sup>)</b>	(0.56-0.68) 0.63	(0.58-0.70) 0.65	(0.60-0.68) 0.65
<b>Total alkalinity (mg/l)</b>	(105-148) 136.03	(110-160) 141.03	(112-162) 142.92
<b>pH</b>	(7.01-7.52) 7.32	(7.32-8.01) 7.65	(7.05-8.40) 7.86
<b>Dissolved oxygen (mg/l)</b>	(5.60-7.32) 6.22	(6.88-7.50) 7.02	6.20-7.30 7.15
<b>TDS (mg/l)</b>	180-320 229.72	240-360 313.67	195-300 241.1

**Table 4.2: Fortnightly Net weight gain of *Pangasius pangasius* at different sites**

Study sites	Net weight gain (gm)					
	Initial	15 <sup>th</sup> day	30 <sup>th</sup> day	45 <sup>th</sup> day	60 <sup>th</sup> day	Total net weight gain (gm)
Site 1	5.71	9.52	26.20	31.14	44.30	111.16
Site 2	5.44	7.14	13.28	19.29	33.20	72.91
Site 3	5.32	6.34	11.26	17.10	23.23	57.93
SEm $\pm$	0.02	0.05	0.14	0.20	0.22	0.15
CD at 0.05	0.05	0.14	0.40	0.60	0.64	0.45

**Data expressed as mean  $\pm$  SEm (n=4)**

**Table 4.3: Fortnightly weight gain% of *Pangasius pangasius* at different sites**

Study sites	Weight gain% (gm)				
	15 <sup>th</sup> day	30 <sup>th</sup> day	45 <sup>th</sup> day	60 <sup>th</sup> day	Average
Site 1	66.72	175.21	72.29	66.81	95.25
Site 2	31.25	128.01	110.62	93.05	90.73
Site 3	19.17	109.14	81.74	120.87	82.73
SEm ±	0.92	2.40	1.76	1.24	1.58
CD at 0.05	2.72	7.50	5.18	3.64	4.76

Data expressed as mean± SEm(n=4)

**Table 4.4: Fortnightly specific growth rate of *Pangasius pangasius* at different sites**

Study sites	SGR growth				
	15 <sup>th</sup> day	30 <sup>th</sup> day	45 <sup>th</sup> day	60 <sup>th</sup> day	Average SGR
Site 1	3.4	6.6	3.6	3.3	4.2
Site 2	1.8	5.4	5.0	4.4	4.1
Site 3	1.1	4.9	3.9	5.2	3.7
SEM $\pm$	0.05	0.09	0.08	0.06	0.07
CD at 0.05	0.14	0.26	0.23	0.16	0.19

**Data expressed as mean  $\pm$  SEM(n=4)**

**Table 4.5: Fortnightly Feed conversion ratio of *Pangasius pangasius* at different sites**

Study sites	FCR (Feed conversion ratio)				
	15 <sup>th</sup> day	30 <sup>th</sup> day	45 <sup>th</sup> day	60 <sup>th</sup> day	Average (FCR)
Site 1	1.13	0.71	2.87	1.52	1.55
Site 2	1.91	0.98	1.46	1.08	1.35
Site 3	2.87	1.04	1.31	1.76	1.74
SEm ±	0.08	0.02	0.06	0.04	0.05
CD at 0.05	0.25	0.05	0.18	0.10	0.14

**Data expressed as mean± SEm(n=4)**

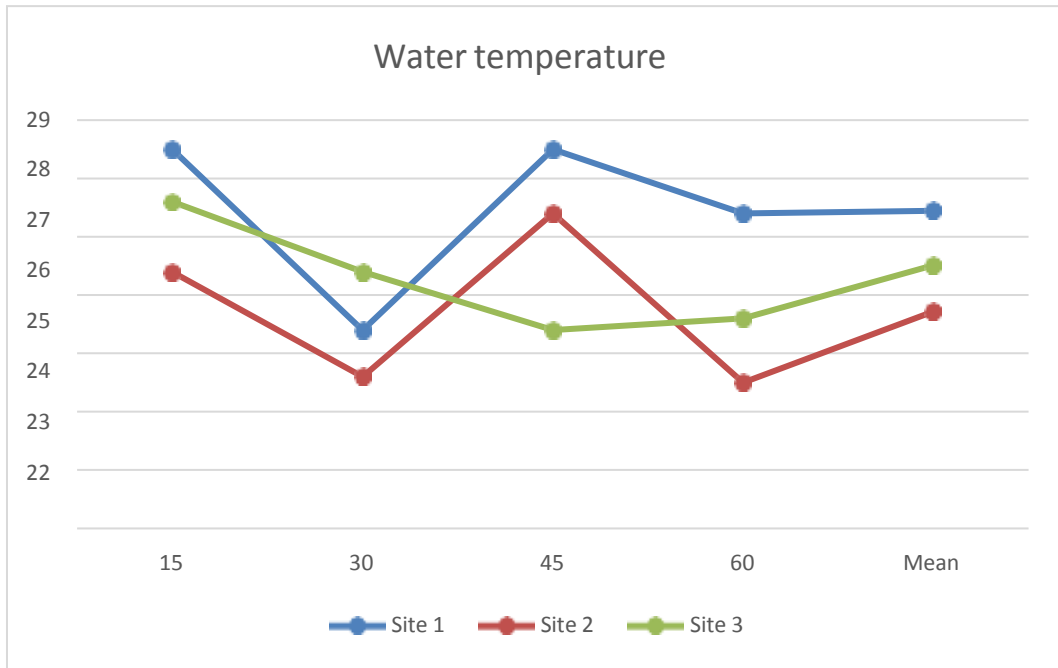
**Table 4.6: Summary of growth parameters of *Pangasius pangasius* at different sites**

Sites	Parameters			
	Net weight gain (g)	Per cent weight gain	SGR	FCR
Site 1	111.16±0.025	95.25±0.028	4.2±0.225	1.5±0.057
Site 2	71.91±0.011	90.73±0.034	4.1±0.005	1.3±0.057
Site 3	57.93±0.024	82.73±0.022	3.7±0.075	1.7±0.058
SEm±	0.15	1.58	0.07	0.05
CD at 0.05	0.45	4.76	0.19	0.14

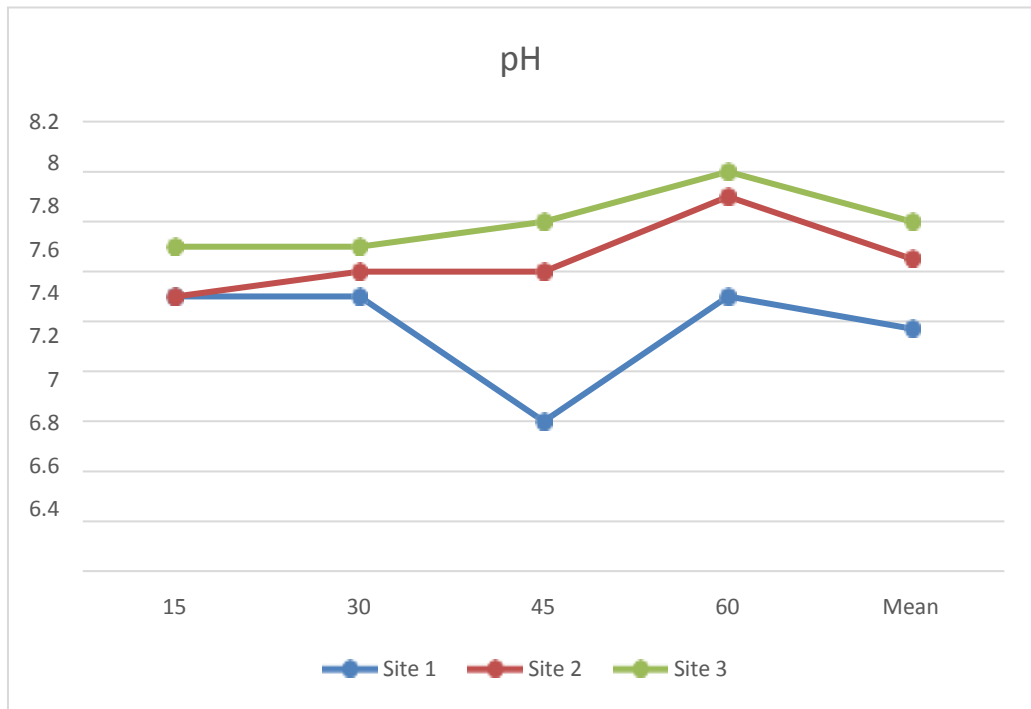
**Data expressed as mean± SEm(n=4)**

**Table 4.7: Economics of *Pangasius pangasius* production at different sites based on cubic meter area for 60 days**

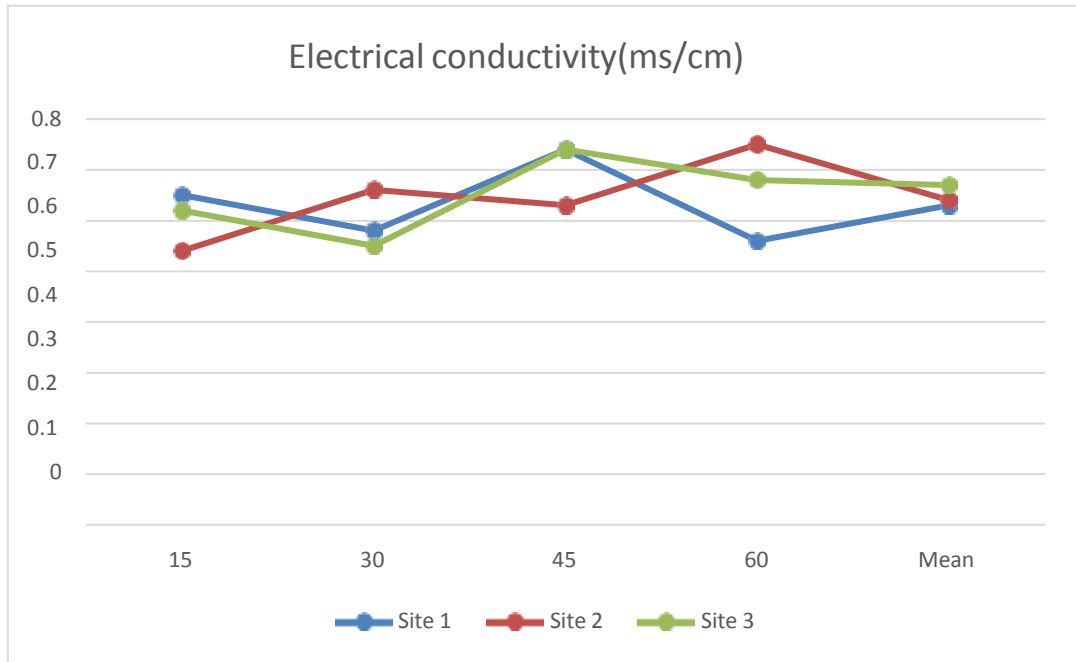
S.No	Growth parameters	Study Sites		
		Site 1	Site 2	Site 3
1	Area of cement cistern (m <sup>3</sup> )	7.65 x 7.65 x 1.5 m		
2	Water depth (m <sup>3</sup> )	1.0 m	1.0 m	1.0 m
3	Stocking density/m <sup>3</sup>	86/ m <sup>3</sup>	97/m <sup>3</sup>	115/ m <sup>3</sup>
	<b>Variable cost</b>			
1	Total feed intake(kg)	877.85	499.18	656.33
2	Total Seed cost@5rs(no.)	430	485	575
3	Total Feed cost (65/kg)	57060	32446	42661
4	Miscellaneous/ Labor cost	2500	2700	2900
5	Total variable cost	59,990	35,631	46,136
	<b>Return</b>			
1	Total production (kg)	548.66	415.99	386.08
2	Total fish production (125 ₹ kg)	68582	51998	48260
3	Net profit/loss	8592	16367	4734
4	Percent return to variable cost	14	45.93	10.26
5	Percent profit to turn over	12.52	31.47	9.80
6	Benefit cost ratio	1.14	1.45	1.04



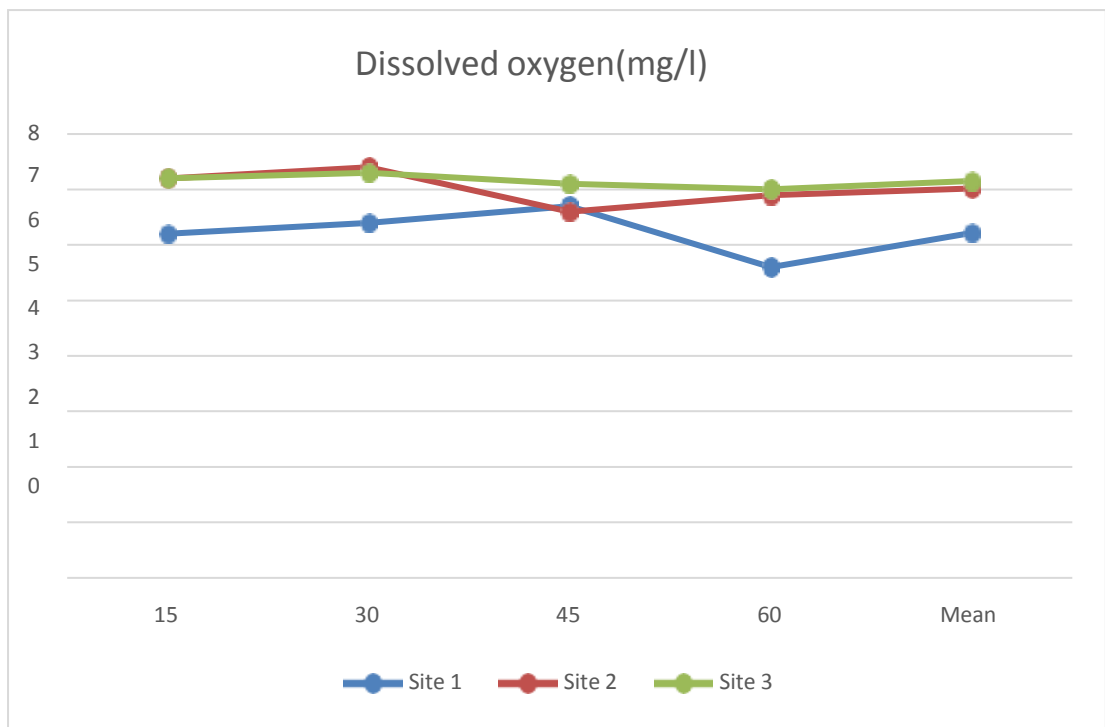
**Fig. 4.1: Water temperature during experimental period with different sites**



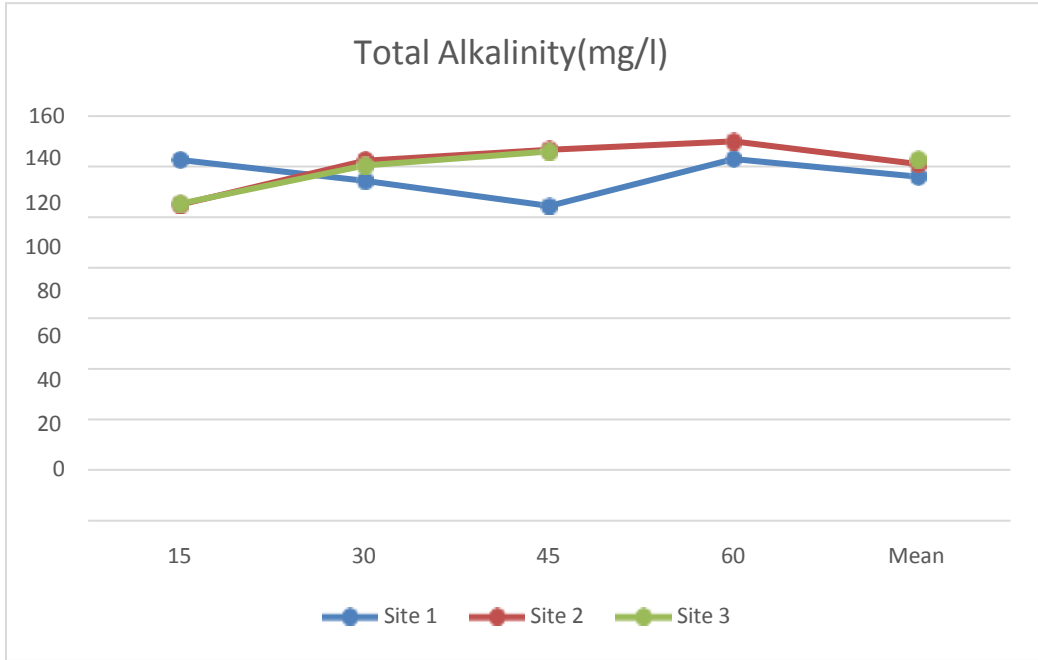
**Fig. 4.2: pH during experimental period with different sites**



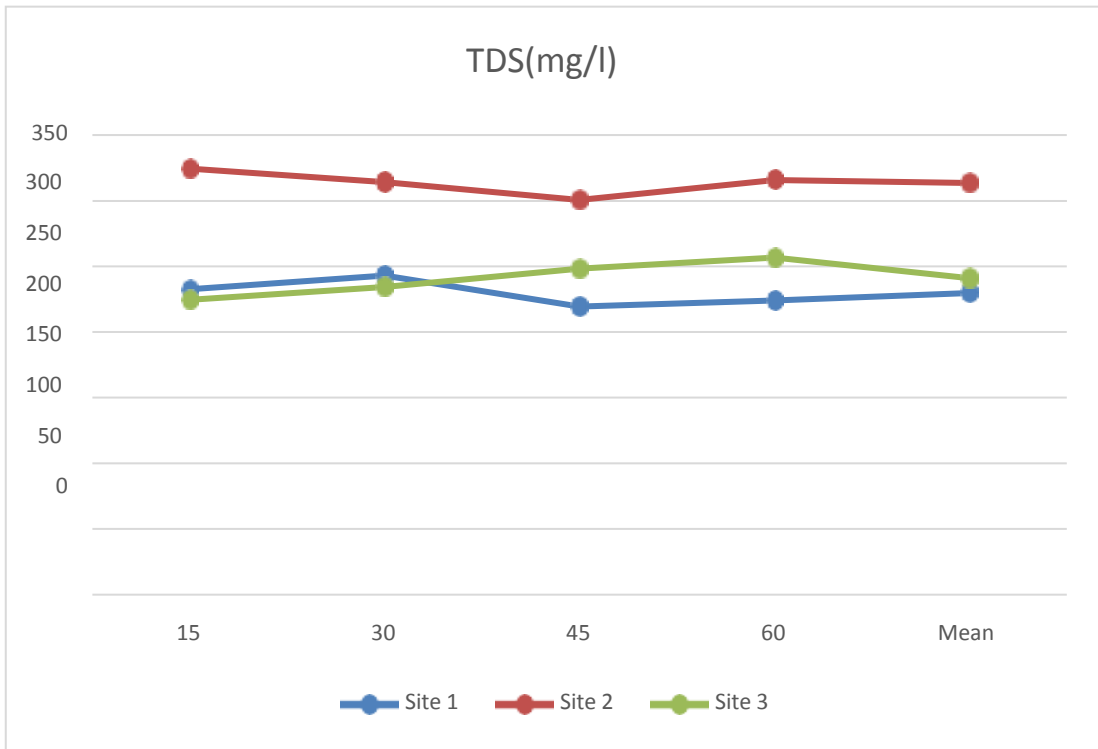
**Fig.4.3: Electrical conductivity during experimental period with different Sites**



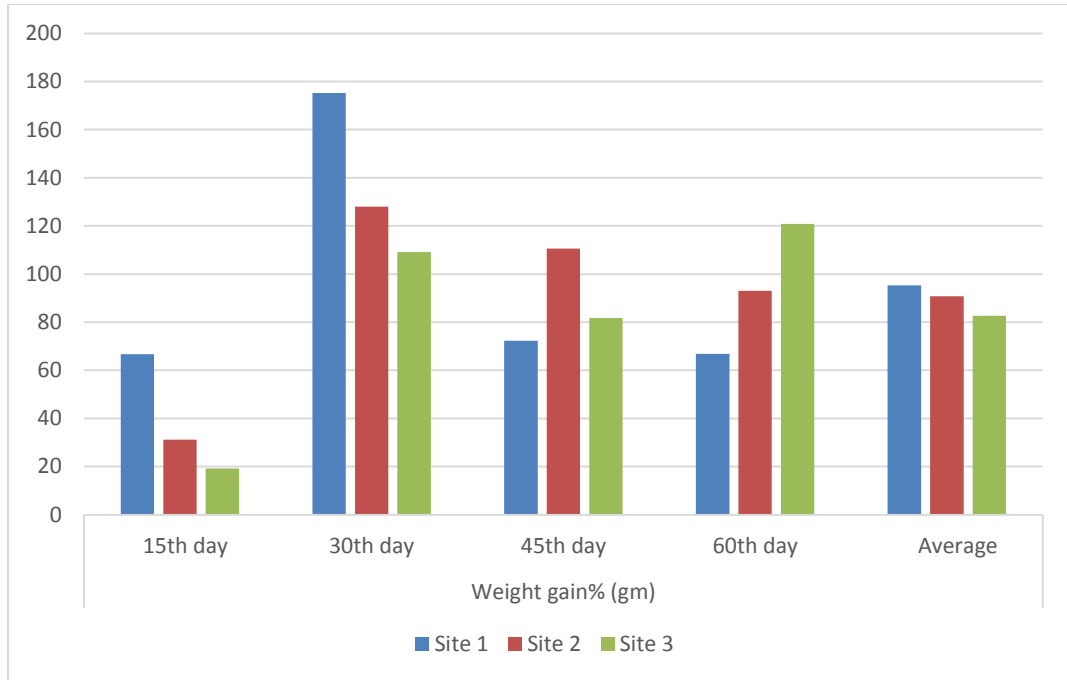
**Fig. 4.4: DO during experimental period with different sites**



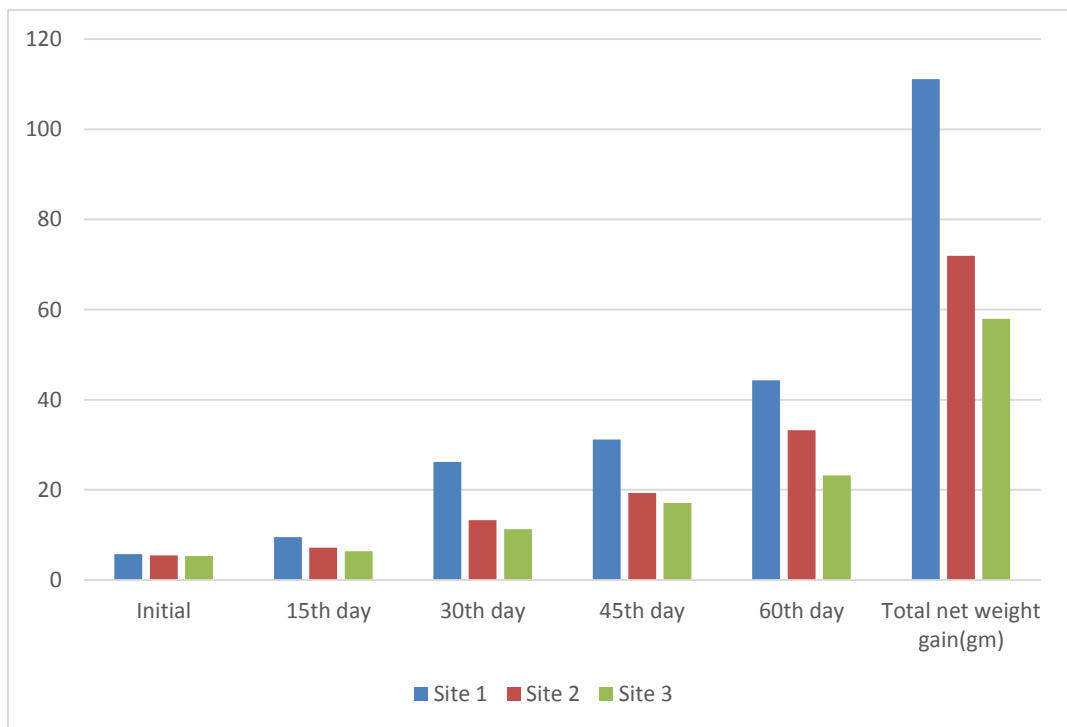
**Fig.4.5: Alkalinity during experimental period with different Sites**



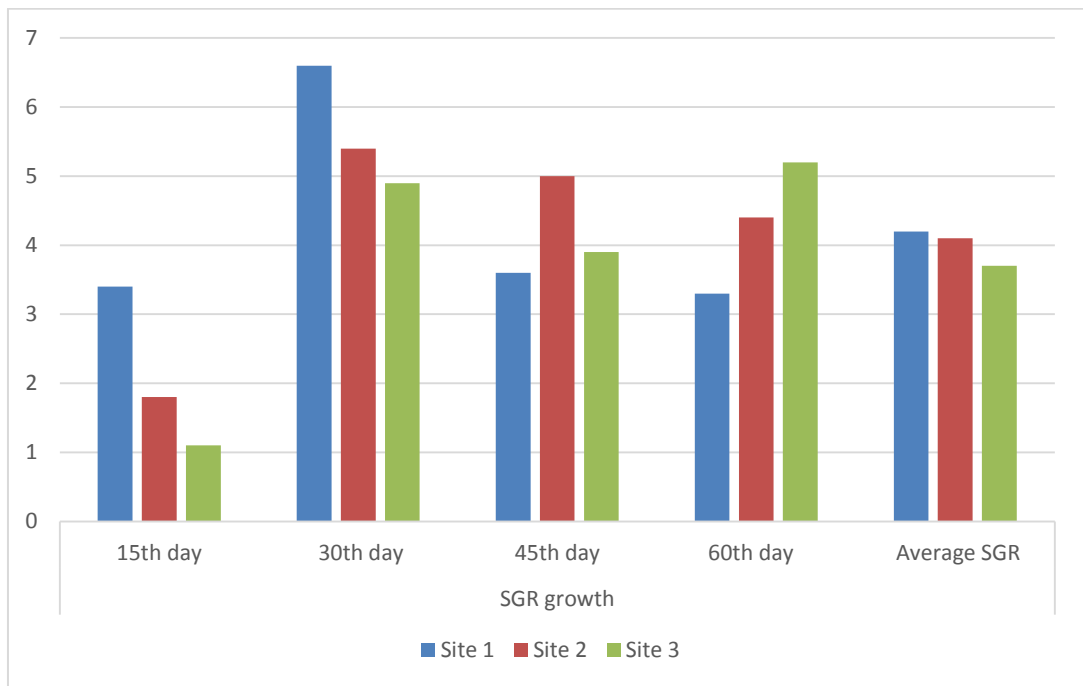
**Fig 4.6 TDS during experimental period with different Sites**



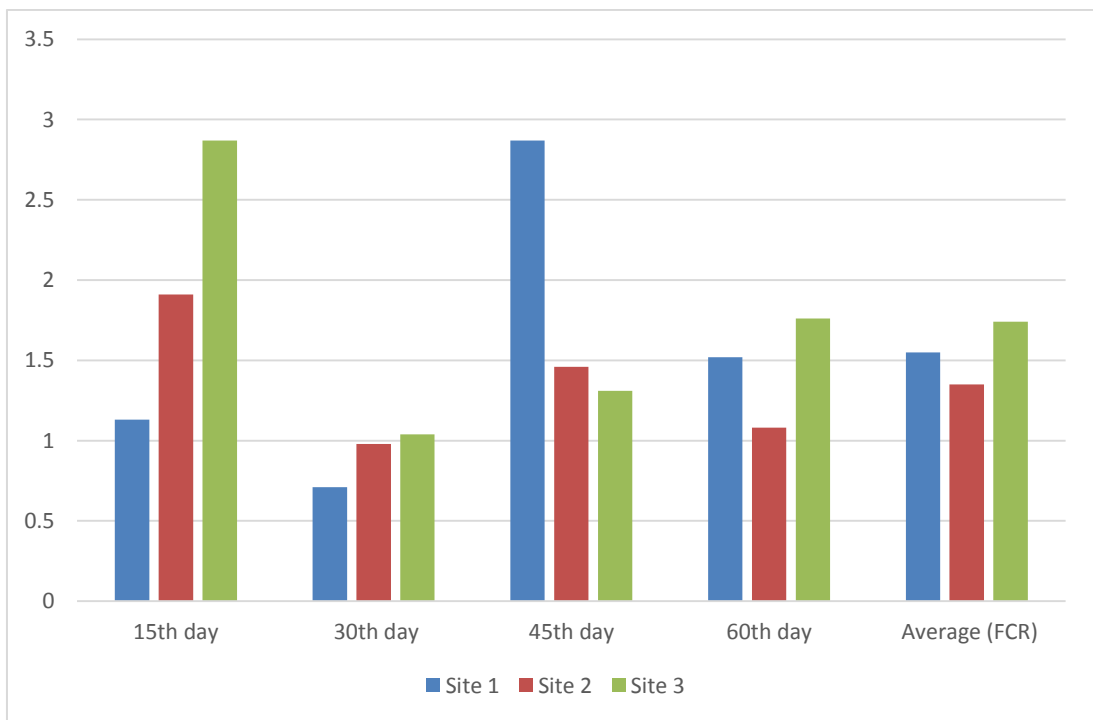
**Fig. 4.7: Fortnightly weight gain (%) of *Pangasius pangasius* with different Stocking density.**



**Fig. 4.8: Fortnightly net weight gain of *Pangasius pangasius* with different Stocking density.**



**Fig. 4.9: Fortnightly Specific growth rate of *Pangasius pangasius***



**Fig. 4.10: Fortnightly feed conversion ratio of *Pangasius pangasius***

## 5. DISSCUSSION

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### 5.1 PHYSICAL PARAMETERS OF WATER

#### 5.1.1 Water temperature

The optimal temperature required for fish culture in a Recirculating Aquaculture System, according to **Bocioc et al. (1987)**, is between 21 and 27 °C. Due to seasonal variations in the ambient temperature, there was a shift in temperature throughout this time.

Quicker growth, improved feed conversion and increased disease resistance are all encouraged by maintaining the optimal temperature (**Masser et al., 1999**). The results of our study agree with those published earlier by Jagadeesh et al. (2007), who found that temperatures between 25.4 and 26.9°C are ideal for fish development and survival. Bregnballe (2015) suggested that a recirculating aquaculture system's intake water enhance the water temperature. Food consumption and temperature have a close relationship up to a point (Cho and Slinger, 1980). During the present study the air and water temperatures were comparable and ranged between 22.6°C to 30.4°C for air and 25.05°C to 27.05°C for water at the three sites.

#### 5.1.2 Electrical conductivity (EC)

According to study by Sinha *et al.* (2013), higher electric conductivity levels are a sign that the water contains more dissolved salts. In the present study, EC was observed in the range of 0.63-0.65 mS/cm. The electrical conductivity that was measured during the experiment agreed with the results of Zhang *et al* (2011).

#### 5.1.3 Total Dissolve Solids

Solid decomposition can have a negative effect on water quality and consequently have an effect on fish health as well as the efficiency of other unit processes in recirculating systems due to the source of increased organic matter in sand filters and inhibition of the bacterial process in biofilters (Chen *et al.*, 1993). (Timmons *et al.*, 2002)

Site 2 had the highest TDS reading (313 mg L<sup>-1</sup>), whereas **Site 1** had the lowest reading (229.72 mg L<sup>-1</sup>). Sharma (2000) states that total dissolved solids range from 10 to 500 mg/L and that, generally speaking, water hardness rises as total dissolved solids levels rise.

Total dissolved solids variations are mostly caused by changes in the ionic composition of water (Gupta and Paul, 2013). The ionic concentration of the water varied according to the treatment groups due to water exchange. The TDS levels in this experiment support of Sharma (2000).

## **5.2 CHEMICAL CHARACTERISTICS OF WATER**

### **5.2.1 pH**

pH change affects the metabolism and other physiological processes (Sott and Sloman, 2004). According to **Bocioc *et al.* (1987)**, a pH of 7-8 is ideal for fish development in RAS. Fish health can also be impacted by pH. According to Martins *et al.* (2009), the pH range of 6.9 to 7.8 is appropriate for fish production in RAS. The findings of the current study were different from those of **Shnel *et al.* (2002)**, where the pH value was measured between 6.1 and 7.6. Site 3 had the highest pH value during the research period (7.8), whereas Site 1 had the lowest (7.37). The higher pH values show that the equilibrium of carbon dioxide, carbonate and bicarbonate is more susceptible to being upset by changes in physico-chemical circumstances (Karanth, 1987). As a result, the pH has to be higher than 7 to sustain a high rate of bacterial nitrification. (Bregnballe, 2015).

### **5.2.2 Dissolved Oxygen (DO)**

For fisheries, dissolved oxygen is a crucial water characteristic. It is extremely important for aquatic organisms to breathe. The concentration of dissolved oxygen changes during the experimental period as a result of variable aeration and water exchange rates. It affects numerous nutrients availability and solubility in aquatic ecosystems (Wetzel, 1983). A big organic matter load may also greatly reduce the DO levels (Yeole and Patil, 2005).

The results of the current analysis are in agreement with those of a prior study by Mohammad *et al.* (2001), which found that the typical DO content for fish culture is 5.9 **mg/L<sup>-1</sup>**. Dissolved oxygen concentrations below 5 **mg/L<sup>-1</sup>** are associated with unproductivity, while concentrations above that threshold are associated with productivity, according to Banerjee (1967).

For intensive culture techniques, it has frequently been recommended to employ DO levels higher than 5 mg L<sup>-1</sup> (Cheng *et al.*, 2003). Dissolved oxygen levels in RAS need to be between 5.9 and 6.9 mg L<sup>-1</sup> for fish to live healthily, according to Ridha and

Cruz (2001). According to Jagadeesh *et al.* (2013) study, the dissolved oxygen concentration varied between 6.93 and 7.80 mg L<sup>-1</sup>. They suggested that this range is suitable for the best fish development in RAS and is acceptable.

### **5.2.3 Total Alkalinity**

Alkalinity is an indicator of water production and is vital to environmental ecology (Banerjee, 1972). Total alkalinity is the collective number of carbonates, bicarbonates, and other ions in water. Strong and weak bases such carbonates, bicarbonates and hydroxide are present in water, according to its quantitative capacity (**Karikari *et al.*, 2013**).

Alkalinity acts as a divider between sudden pH shifts (Pant, 2015). Highly alkaline waters provide a higher buffer against pH change than fluids with less alkalinity (Losordo *et al.*, 1998).

Limited alkalinity water, defined as having a total alkalinity of less than 20 **mg/L<sup>-1</sup>**, has a low buffering ability and exhibits large pH fluctuations (Boyd, 1982). The decomposition of organic waste is one of the likely explanations of the rise in carbonate and bicarbonate levels and consequent rise in alkalinity (Jain *et al.*, 1997; Chaurasia and Pandey, 2007). According to Boyd (1982), fish require a total alkalinity range of 20 to 300 mg L<sup>-1</sup>; anything below that causes stress.

## **5.3 GROWTH PERFORMANCE OF FISH**

### **5.3.1 Weight gain**

The environment has a big influence on how fish feed, such as water temperature, DO and TAN (Buentello *et al.*, 2000; Meinelt *et al.*, 2010; Pang *et al.*, 2011). It may also have an impact on how much weight you put on.

At the conclusion of the study, the fish grew most rapidly at Site 1, where water quality was kept up as the highest weight gain was at Site 1(111.16 gm) and lowest was at Site 3-57.93 gm. Fish growth was found to be slow at Site 3. It may be because there has been less water recirculation, which has a detrimental effect on fish development, as well as a larger buildup of organic materials, low DO, high CO<sub>2</sub>, and fluctuating water temperatures. If water quality is raised in RAS, fish may eat their food more rapidly and grow bigger.

The highest percentage weight gain was noticed at Site 1 and the lowest was at the Site 3. The highest percentage weight gain was at site 1-95.25% and lowest was in site 3- 82.73%. RAS provides optimum environmental conditions all year long, raising FCR and improving fish welfare (**Losordo *et al.*,1999 and Roque d'Orbcastel *et al.*, 2008**).

### **5.3.2 Specific growth rate**

According to research by Enache *et al.* (2011), the SGR varied between 1.28% and 1.49% in several treatment groups during the production of carp in RAS. The highest SGR was at site 1-4.2% and lowest was at site 3-3.7%. In this investigation, SGR conclusions are less important than those of Enache *et al* (2011). The SGR's value in the production of Pangas is good.

### **5.3.3 Feed Conversion Ratio (FCR)**

The RAS enhances the environmental conditions year-round, contributes to the preservation of fish health and lowers the FCR, increasing feeding effectiveness (Roque d'Orbcastel 2009). Site 2 therefore had the greatest FCR, which was considerably ( $P<0.05$ ) greater than all other sites.

Lin *et al.* (2003) found that the FCR in a RAS was (lower 1.65 vs. a culture pond 2.25). The conclusions of our study are in agreement with those of Zhang *et al.* (2009), who found FCR ranges of 1.54 to 1.84 in several treatment groups during fish production under RAS.

## **5.4 ECONOMIC ANALYSIS**

Economic research revealed that, when compared to production, discounts in cost-of-production factors including labor, feed and power had marginal effects on profitability. The experiment was carried out by Caffey and Kazmierczak (1996) in order to develop a thorough aquaculture production model that considers restrictions unique to closed system culture and to undertake a rigorous economic study of closed system operation. However, if high protein feed consumption continues through harvest, the higher direct feed costs and indirect expenses caused by metabolic responses result in lower daily returns. This is true even though higher protein levels stimulate growth and are often used in the industry for this purpose. As the efficacy of biological filters decreases, harvest time lengthens and returns diminish at an increasing pace. Research also demonstrates that when stocking density rose, direct returns

benefits were only assured in the absence of metabolic feedbacks. If the filter technology is not employed properly, a higher stocking density might lead to financial failure.

Overall, it was discovered that there had been very little public or private investment in creating it as a tool for growth. Instead of a larger project that ultimately produced greater value, a small yet lucrative project with a high benefit-cost ratio can be chosen (Engle, 2010).

## 6. SUMMARY AND CONCLUSION

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This study was aimed as comparative study to assess the growth performance of *Pangasius pangasius* at different stocking density and also to analyze the economic feasibility of RAS of different locations of Varanasi district, Uttar Pradesh, India. The experiment was carried out from august 2022 to October 2022 at different sites in different locations of Varanasi, Uttar Pradesh. There was total 8 cemented tanks at each site (size 7.65 x 7.65 x 1.5 m) with approximately 1 lakh litre water capacity. The stocking density was in site 1-86 /m<sup>3</sup>, site 2-97/m<sup>3</sup> and site 3-115m<sup>3</sup> healthy and disease-free fingerlings of *Pangasius pangasius* from same age group. The stocked fingerlings were fed twice a day with commercial floating feed at the rate 6.5%-8%body weight.

### **OBJECTIVES: -**

1. To study the growth performance of *Pangasius pangasius* in relation to different stocking densities in different locations at commercial Recirculatory Aquaculture System (RAS).
2. To Study certain water quality parameters of RAS.
3. To study the comparative economics of fish production in different RAS.

The investigation of water quality indicators, fish growth and production, economics, etc. was done using established procedures in order to accomplish the aforementioned goals. Temperature of the water, electrical conductivity and total dissolved solids were examined as physical factors.

The water temperature, electrical conductivity and total dissolved solids ranged from 25.8 to 26.1°C, 0.63 to 0.65 mS/cm, and 229.72 to 313.67 mg L<sup>-1</sup>, respectively, during the study period. Site 3 had the greatest temperature, whereas Site 2 had the lowest. Site 1 reported the lowest conductivity value, whereas Site 3 recorded the greatest value. Site 2 obtained the greatest total soluble solids value, whereas Site 1 recorded the lowest.

Alkalinity, dissolved oxygen, and pH were examined in chemical parameters. Water's pH, oxygen dissolving capacity and alkalinity concentrations ranged from 7.3 to 7.8, 6.22 to 7.15 mg L<sup>-1</sup> and 136 to 142 mg L<sup>-1</sup>, respectively. Site 3 had the highest pH reading during the examination, whereas Site 1 had the lowest. Site 3 had the

greatest concentration of dissolved oxygen, whereas site 1 had the lowest concentration. Site 3 had the greatest alkalinity readings, whereas site 1 had the lowest readings.

In terms of growth metrics, the trial site 1 (111.16) recorded the best Net weight gain, followed by site 2 (72.91) and site 3. (57.93). Fish from site 2 (1.35), site 1 (1.55), and site 3 (1.74) had the highest Feed Conversion Ratio (FCR) values (1.74). Fish from site 1 reported the greatest Specific Growth Rate (4.2%), followed by fish from site 2 (4.1%), and fish from site 3 (3.7%). The biggest net profit was recorded at site 2 ranged from Rs 4734 to 16367. The project's average cost-benefit ratio came at 1.04:1.45.

Based on the experimental data collected to see the effect of rearing tank capacities on different economic tools. The economic analysis clearly showed that recirculation system for Pangas culture is not commercially feasible in Uttar Pradesh. Outcomes of this study can be used by policymakers (such as the Ministry of Agriculture and Rural Development of Uttar Pradesh) and private sectors (retailers and farmers) to assess the robustness of the economic performance of RAS for Uttar Pradesh pangasius farms. The key variables influencing the profitability of RAS provide a basis for policy recommendations. For instance, to help farmers cope with the relatively high initial investment costs for setting up the RAS system, governments could provide free-interest loan programs to Pangasius farmers who are willing to implement RAS on their farms. Furthermore, farmers who implement RAS expect a price premium for their product and higher yield to partially compensate for the high investments.

The results of this study suggest that perhaps component performance should be combined with the cost of ownership of these components (which ultimately make up the total cost of the system) into a “performance/cost” factor. Engineering performance and economic performance must be balanced to provide an optimum production system for the specific site, species and operating personnel requirements.

The challenges for recirculating systems designers and engineers are many. Recirculating systems and system components must be designed to be manufactured at a lower cost or to utilize components that are currently available to other industries at lower prices. Where possible the carrying capacity of a system must be increased without increasing cost or sacrificing system reliability.

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# Comparative study of growth performance in *Pangasius pangasius* at different locations of Varanasi (Uttar Pradesh) at commercial recirculatory system

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## ABSTRACT

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The purpose of this study is to compare the pangas growth performance at different stocking densities in commercial recirculating aquaculture systems (RAS) at different locations of Varanasi district of Uttar Pradesh, India. The goal of the study was to evaluate the yield and economics of *Pangasius pangasius* as well as the stocking density for optimum *Pangasius pangasius* growth in RAS. There were 3 separate research locations, each with 8 tanks totaling 7.65 × 7.65 x 1.5 metres in size (water volume capacity-100000L). Average body weight of 5-6 gm fish were distributed @ 86,97 and 115 per m<sup>3</sup> at sites 1, 2 and 3 respectively. Fed with commercial feed being given at the rates of 6.5%-8 body weight.

The result showed significant ( $p < 0.05$ ) response in the growth performance of fish. The growth performance results were in following order:

Net Weight gain: 111.16±0.59 g (Site 1) > 72.91 ±0.54g (site 2) > 57.93±0.58g (Site 3).

Percent weight gain: 95.25 (Site 1) > 90.73 (Site 2) > 82.73 (Site 3).

SGR: 4.2 (Site 1) > 4.1 (Site 2) > 3.7 (site 3).

FCR: 1.35 (Site 2) > 1.55 (Site 1) > 1.74 (Site 3).

Throughout the experiment, the physical characteristics of the water including its temperature, electrical conductivity and total dissolved solids were measured every two weeks and ranged from 25.7 to 27.5°C, 0.63 to 0.65 mS/cm, and 229.72 to 313.67 mg/L, respectively. The crucial chemical characteristics of water, including pH, oxygen dissolution, and alkalinity, which ranged from 7.3 to 7.8, 6.22 to 7.15 mg/L, and 136.03 to 142.92 mg/L, respectively, were also examined. The obtained results indicated that the best growth performance of Pangas was found in Site 1 as compared to other Sites, which realized positively significant at level of 5%. The cost benefit ratio of total fish production was computed as 1.04:1.45. The results of the economic evaluation suggested that there could be a chance for significant production cost reductions.

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वाराणसी (उत्तर प्रदेश) के विभिन्न स्थानों पर पुनरावर्तन जलीय कृषि प्रणाली में  
पंगोसियस पंगोसियस में वृद्धि प्रदर्शन का तुलनात्मक अध्ययन

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## अनुक्षेपण

इस अध्ययन का उद्देश्य भारत के उत्तर प्रदेश के वाराणसी जिले के विभिन्न स्थानों पर व्यावसायिक पुनरावर्तन जलीय कृषि प्रणाली में विभिन्न स्टॉकिंग घनत्व पर पंगोस के विकास के प्रदर्शन की तुलना करना है। अध्ययन का लक्ष्य पंगोसियस पंगोसियस की उपज एवं अर्थशास्त्र के साथ-साथ आरएएस में इष्टतम पंगोसियस पंगोसियस विकास के लिए स्टॉकिंग घनत्व का मूल्यांकन करना था। 3 अलग-अलग अनुसंधान स्थान थे, जिनमें से प्रत्येक में कुल  $7.65 \times 7.65 \times 1.5$  मीटर आकार के 8 टैंक थे (पानी की मात्रा क्षमता – 100000 लीटर)। साइट 1, 2 और 3 पर क्रमशः 5-6 ग्राम मछली का औसत वजन 86, 97 और 115 प्रति घन मीटर की दर से वितरित किया गया। 6.5 प्रतिशत-8 प्रतिशत भार की दर से वाणिज्यिक आहार दया जा रहा है।

परिणाम ने मछली के विकास प्रदर्शन में महत्वपूर्ण ( $p < 0.05$ ) प्रतिक्रिया दिखाई। विकास प्रदर्शन के परिणाम निम्नलिखित क्रम में थे –

शुद्ध भार बढ़ना :  $111.16 \pm 0.59$  ग्राम (साइट 1)  $>$   $72.91 \pm 0.54$  ग्राम (साइट 2)  $>$   $57.93 \pm 0.58$  ग्राम (साइट 3)।

प्रतिशत वजन बढ़ना :  $95.25$  (साइट 1)  $>$   $90.73$  (साइट 2)  $>$   $82.73$  (साइट 3) ।

एसजीआर :  $4.2$  (साइट 1)  $>$   $4.1$  (साइट 2)  $>$   $3.7$  (साइट 3)।

एफसीआर:  $1.35$  (साइट 2)  $>$   $1.55$  (साइट 1)  $>$   $1.74$  (साइट 3) ।

पूरे प्रयोग के दौरान, पानी की भौतिक विशेषताएं – इसके तापमान, विद्युत चालकता और कुल घुलित ठोस को हर दो सप्ताह में मापा गया और  $25.7$  से  $27.5^\circ\text{C}$ ,  $0.63$  से  $0.65$  mS/cm, और  $229.72$  से  $313.67$  mg/l। पीएच, ऑक्सीजन विघटन और क्षारीयता सहित पानी की महत्वपूर्ण रासायनिक विशेषताओं, जो क्रमशः  $7.3$  से  $7.8$ ,  $6.22$  से  $7.15$  मिलीग्राम/लीटर और  $136.03$  से  $142.92$  मिलीग्राम/लीटर तक थी। प्राप्त परिणामों ने संकेत दिया कि अन्य साइटों की तुलना में साइट 1 में पंगोस का सबसे अच्छा विकास प्रदर्शन पाया गया, जो 5% के स्तर पर सकारात्मक रूप से महत्वपूर्ण पाया गया। कुल मछली उत्पादन के लागत लाभ अनुपात की गणना  $1.04:1.45$  के रूप में की गई थी। आर्थिक अनुसंधान के परिणामों ने सुझाव दिया कि महत्वपूर्ण उत्पादन लागत में कमी की जा सकती है।

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