



Aquaponic innovations: Optimizing carp growth in polyculture tank with plant diversity in Himachal Pradesh

MEENAKSHI SHARMA¹, TARUN VERMA¹ and ARZOO SHARMA¹

Sri Sai University, Palampur, Himachal Pradesh

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ABSTRACT

Aquaponics integrates aquaculture and hydroponics, addressing the decreasing agricultural land in Himachal Pradesh. The rapid urbanization has led to an increased demand for nutritious food, especially protein-rich foods such as fish and fresh vegetables, as urban dwellers increasingly prioritize healthy eating habits. This 60-day experiment cultivated fingerlings of *Hypophthalmichthys molitrix*, *Cyprinus carpio*, *Ctenopharyngodon idella*, *Cyprinus rubrofuscus*, and *Labeo dero* alongside plants like *Chenopodium album*, *Spinacia oleracea*, *Coriandrum sativum*, *Mentha spicata* and *Mentha piperita*. Optimal water quality was maintained. Fish exhibited growth with an average length increase of 4.8 ± 1.33 cm and weight gain of 16.05 ± 3.76 g, achieving a feed conversion ratio (FCR) of 2.84 ± 0.75 . Plant growth averaged 30.15 ± 0.91 cm, surpassing traditional methods. *Hypophthalmichthys molitrix*, *Cyprinus carpio*, *Ctenopharyngodon idella*, and *Cyprinus rubrofuscus* showed superior growth compared to *Labeo dero*. This study demonstrates aquaponic's potential as a sustainable farming method, enhancing water efficiency and food security amidst land constraints.

Keywords: Aquaponics, Fish growth, Food security, Plant growth, Sustainable farming, Water quality

Agriculture stands as an exclusive “practice” that sustains human life and serves as a primary source of wealth (Pretty 1999). The population of the globe has increased dramatically in recent decades (Faostat and Production 2018). Currently, the world's population exceeds seven billion, with projections from the UN suggesting that it will reach 9.7 billion by 2050. Over the past 50 years, as agricultural land has become less available for agriculture, food security has decreased on a local, regional, and worldwide scale (Cottrell *et al.* 2019). According to current estimations, the world's food demand by 2030 could surpass 350 million metric tons, while output is likely to remain at 200 million metric tons, resulting in a surplus demand of more than 100 million metric tons. Aquaculture emerges as a critical farming technique, providing essential animal protein affordably, given that agricultural products and outputs alone cannot adequately feed such a vast population (Kaleem and Sabi 2020). In aquatic sources, aquaculture wastes are discharged from intensive aquaculture systems, resulting in wastage of large amounts of water and pollution of natural aquatic habitats. One of the most important aspects of cutting-edge and sustainable food production technology is the reuse of water in intensive or semi-intensive production systems (Ahmad *et al.* 2016, Haridas *et al.* 2017).

Present address: Sri Sai University, Palampur, Himachal Pradesh. ✉Corresponding author email: msharmahpkv1983@gmail.com

Aquaponics is a cutting-edge farming technique that combines fish farming and soilless crop cultivation, offering a promising solution for sustainable food production has gained widespread acceptance in recent times (Mandal *et al.* 2023). Aquaponics offers a sustainable solution to mitigate environmental impacts of aquaculture by recycling wastewater, providing a distinct advantage over traditional practices (Estim *et al.* 2022, Suárez-Cáceres *et al.* 2021). Plants absorb excess nutrients, purifying the water, which is then recirculated to nourish the fish (Lobanov *et al.* 2021).

Aquaponic farming supports over 12 fish species and 150+ types of vegetables, herbs, and flowers, making it a versatile and sustainable farming method (Kaleem and Sabi 2020).

This research aims to unlock aquaponics' potential in Himachal Pradesh, exploring its viability and adaptability in the region's unique climate and geography, to develop a sustainable food system.

MATERIALS AND METHODS

Study area: This study was undertaken at Sri Sai University, Palampur, situated in the cold hilly terrain of Himachal Pradesh. The area has an average annual temperature of 16.8°C and receives around 1578 mm of rainfall each year.

Fish and plants used: The fingerlings of *Hypophthalmichthys molitrix*, *Cyprinus carpio*, *Cyprinus rubrofuscus*, *Ctenopharyngodon idella* and *Labeo dero* were sourced from Arjun fish farm, Palampur, Himachal

Pradesh, with an average length of 9.8 ± 0.87 cm. The plant saplings named *Chenopodium album*, *Mentha piperita*, *Mentha spicata*, *Spinacia oleracea* and *Coriandrum sativum* 10 days after germination were planted in nutrient film technique (NFT) pipes.

Experimental design: For aquaponic setup (Fig. 1), circular fiber-reinforced plastic (FRP) tank with a 750 L water holding capacity was used. The FRP tank measured 0.9 meters in height. Over the trickling filter bed, water from the fish culture tank was pushed continuously. The pump (VarSky Heavy duty 0.25 HP manufactured by Peerzada and Co.) that was employed had a volumetric flow rate (QMAX), head (HMAX), and wattage of 1100 L/h, 1.85 m, and 22 W, respectively. Gravel in a plastic bucket with a size range of 10 to 25 mm was used to create a trickling filter. The filter bed was filled with water that was piped from the fish tank which was further connected to NFT pipes and from these pipes water is sent back to fish tank.

Fish feed: The feeding regimen consisted of a 42% crude protein formulated diet, Acuastar 42 carat gold standard, administered twice daily at 1000 and 1400 hours. This fed was specifically designed for aquatic species and was manufactured, packed and marketed by ABIS exports, India Pvt. Ltd.

Surveillance of water quality parameters: Water quality monitoring was conducted twice a week to ensure optimal conditions in the tank. Temperature, electrical conductivity and pH, were measured weekly using a bulb thermometer for air and water temperature in °C, an electrical conductivity meter (Manufactured by Max electronics India, model no. 976 and S. No. 987) for EC levels in μScm^{-1} , and a pen-style pH meter for pH levels. Dissolved oxygen (DO), alkalinity, ammonia, nitrate and nitrite levels were assessed by using modified conventional APHA (2005) procedures.

Statistical analysis of growth parameter measurements: A randomized sample of five fingerlings from each species was collected fortnightly from a tank with a stocking density of $100/\text{m}^3$ for a period of two months to obtain weight and length measurements. The fingerlings were weighed to an accuracy of 0.01 g using a high-precision scale, and their lengths were measured using a centimetre scale. This sampling design allowed for the collection

of longitudinal data on growth patterns in each species, enabling the assessment of changes in weight and length over time. Similarly, the length, weight, SGR and FCR of plants were also measured as per modified methods of Ujjania (2021) and Saufie *et al.* (2015).

With the aid of Microsoft Office Excel 365, the gathered data, which included fish and plant growth metrics and water quality parameters, were computed and graphic presentations were created for the examination of growth parameters.

RESULTS AND DISCUSSION

Water quality parameters: Water quality was rigorously assessed on a weekly basis and systematically recorded (Table 1) for easy reference and future analysis. This diligent monitoring ensured the consistency and reliability of the water source, supporting the integrity of the experiment. This study investigated the growth of fingerlings in an aquaponic system and the impact of fish waste on plant growth. The results showed that optimal water quality parameters are crucial for the development and survival of both fish and plants (Barker *et al.* 2009). Water temperature, for instance, played a significant role in fish development, with a range suitable for growth (Kohinoor 2000, Bhatnagar and Devi 2013). This temperature range allowed for optimal metabolic activity, feeding, and growth in the fish. In addition to temperature, pH levels were also critical for fish growth (DeLong *et al.* 2009, Zou *et al.* 2016). Slightly alkaline environment allowed for proper osmoregulation, nutrient uptake, and waste removal in the fish. The monitoring of pH levels allowed the identification and management of any sudden change ensured a stable environment. Electric conductivity, which measures the ability of water to conduct electricity, was also within the suitable range (Table 1) (Ogbeibu and Egborge 1995, Stone and Thomforde 2004). The desired range indicated a balanced level of dissolved ions and nutrients in the water. Dissolved oxygen levels were also maintained above 5 mg/L, which is suitable for fish growth (Masser *et al.* 1999, Ekubo and Abowei 2011). This ensured that the fish had sufficient oxygen for respiration, metabolic activity, and growth. Total alkalinity measures the water's ability to buffer pH changes and was favorable for fish growth (Buttner *et al.* 1993, Eissa *et al.* 2015). This range allowed for stable pH levels and prevented sudden changes that could stress the fish. The effective waste management and healthy environment required the estimation of ammonia, nitrate, and nitrite levels which could impair their health and growth. Ammonia, nitrate, and nitrite levels were also within acceptable ranges (Nijhof and Bovendeur 1990, Van Rijn and Rivera 1990, Rakocy *et al.* 2006).

These parameters are critical for fish health, as high levels can be toxic and even lethal. By maintaining optimal water quality parameters, the aquaponic system was able to foster healthy growth and development of both fish and plants.

Fish-plant growth: Regular weight monitoring is crucial

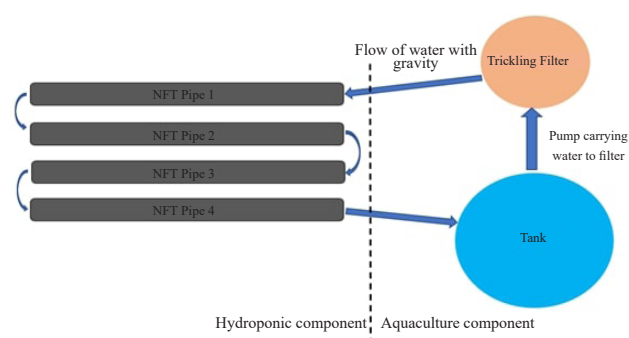


Fig. 1. Experimental design

Table 1. Average values of water parameters recorded during the experiment

Parameter	Average value	Standard value
Air temperature (°C)	18.62±3.75	-
Water temperature (°C)	17.73±3.70	15-30°C (Bhatnagar and Devi 2013)
pH	7.69±0.14	7.5-9 (Zou <i>et al.</i> 2016)
Dissolved oxygen (DO) (mg/L)	6.61±0.14	>5 mg/L (Masser <i>et al.</i> 1999)
Electrical conductivity (µS/cm)	157.54±2.86	100-2000 µS/cm (Stone and Thomforde 2004)
Alkalinity (mg/L)	114.97±5.74	5-200 mg/L (Eissa <i>et al.</i> 2015)
Ammonia (mg/L)	0.0017±0.0004	<1 mg/L (Nijhof and Bovendeur 1990)
Nitrate (mg/L)	0.061±0.014	0.1 mg/L (Rakocy <i>et al.</i> 2006)
Nitrite (mg/L)	0.045±0.008	0.1 mg/L (Rakocy <i>et al.</i> 2006)

for accessing overall growth performance and health, guiding future improvements in aquaculture practices. A comparative analysis of growth patterns over a 60-day experimental period revealed significant interspecific variations. *C. rubrofasciatus* showed remarkable growth, with a mean length of increase of 5.9 cm (from 9±0.36 cm to 15.1±0.37 cm) and a mean weight gain of 20.3 g (24.84±0.08 g to 44.87±0.04 g), while *L. dero* exhibited modest growth, with a mean length increase of 2.5 cm (from 9±0.22 cm to 11.5±0.23 cm) and a mean weight gain of 10.84 g (from 19.04±0.11 g to 29.88±0.23 g). *H. molitrix* matched *C. rubrofasciatus* SGR of 0.99, while *L. dero* had the highest FCR at 3.99 (Fig. 2 and 3). Observed differences in SGR among the species can inform species selection and management practices in aquaculture. In addition, the observed FCR values guided improvements in feed formulations and management practices to enhance growth performance and reduced feed costs. Monitoring plant growth assessed nutrient management and environment condition's effectiveness in supporting health and productivity. *S. oleracea* displayed the highest growth,

with a mean length increase of 31.36 cm (from 16.8±0.27 cm to 48.1±0.37 cm) and a mean weight gain of 47.89 g (from 1.25±0.02 g to 49.1±0.16 g), whereas *C. sativum* showed lower growth rates. These results highlighted significant interspecies variations in growth patterns. The study highlights the potential of aquaponics as a sustainable method for enhancing food production efficiency while minimizing environmental impact (Rakocy 1999).

By integrating fish and plant production, aquaponics can increase crop yields, reduce water usage, and minimize waste. This approach can contribute to a more sustainable food production system, which is essential for meeting the world's growing food demands. The study highlights the potential of aquaponics as a sustainable method for enhancing food production efficiency while minimizing environmental impact (Rakocy 1999). By integrating fish and plant production, aquaponics can increase crop yields, reduce water usage, and minimize waste. This approach can contribute to a more sustainable food production system, which is essential for meeting the world's growing food demands.

In conclusion it can be stated that aquaponics demonstrates a promising solution for enhanced productivity where this groundbreaking approach has earned widespread acclaim for its ingenious use of water bodies to cultivate both fish and plants, providing a beacon of hope for environmentally sustainable farming practices in flood-prone and coastal regions. The economic viability of this aquaponics system is driven by its favorable financial metrics, including low initial capital expenditures, minimal risk exposure, and rapid return on investment. Present work was done to explore the growth of fingerlings and plants in an aquaponic system, finding excellent growth in all plant species, with a 30.15% increase in length and 26.84% weight gain. The balanced aquaponic system effectively supported the development of plant and fish growth parameters, suggesting that aquaponics can be a sustainable solution for regions with limited space and agricultural constraints, offering a promising alternative to traditional farming practices.

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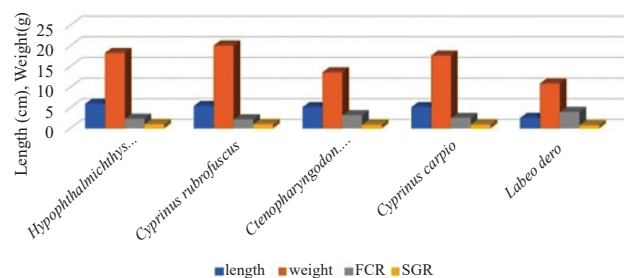


Fig. 2. Fish growth

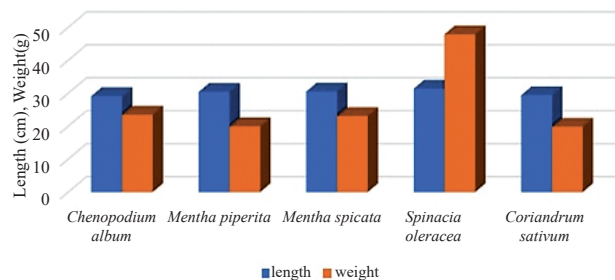


Fig. 3. Plant growth

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