Research Article

Aquaponic Recirculating System: Impacts of Different Stocking Densities on Growth Performance of *Lepidocephalichthys guntea*, Water Quality and Plant Growth

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Abstract: This present study was conducted to evaluate the effects of different stocking densities of vegetable plants on growth and feed utilization in *Lepidocephalichthys guntea* in aquaponics. A feed with 35% protein was provided to the experimental fish during the feeding trial. The trial was performed in three groups of tanks, a control tank (without plants) (T1), an aquaponics setup tank having 15 plants (5 Brinjals- *Solanum melongena L.*; 5 Tomatoes- *Solanum lycopersicum* and 5 Chilies- *Capsicum annuum L.*) (T2) and an aquaponic setup with 9 plants (3 Brinjals, 3 Tomatoes and 3 Chilies) (T3). 30 Lepidocephalichthys *guntea* species (initial weight ± SE, 1.25 ± 0.08 g) were stocked in FRP tanks for 30 days of feeding trial. Results showed no significant (p>0.05) difference in the water quality parameters *viz*. dissolved oxygen; alkalinity, pH and temperature. Significantly (p<0.05) higher weight gain, specific growth rate, protein efficiency ratio and better feed conversion ratio were observed in T2. Significantly (p<0.05) different length of plants (Brinjal, Tomato and Chili) was found in T2 and T3 between the initial, 10, 20 and 30 days of feeding trial. This study concluded that the aquaponics system not only ameliorated the growth of fish but also the growth of cultivated plants.

Keywords: Aquaponics; Feed utilization; Growth performance; *Lepidocephalichthys guntea*; Plant growth; Water quality.

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1. Introduction

RAS and hydroponics are two well-known systems that are symbiotically combined to create aquaponics. By transporting nutrients from aquaculture to hydroponics and recycling nutrients in hydroponics, this technology uses less water (Turcios and Papenbrock, 2014). Aquaponics, which is basically the combined culture of fish and plants in a recirculating system, is one of the most effective and environmentally friendly ways of the twenty-first century. Dissolved nutrients that are either directly excreted by fish or produced by the microbial decomposition of fish faeces help plants grow quickly.

Bacteria in the recirculatory system convert ammonia to nitrite and ultimately to nitrate, requiring very little daily water exchange. Nitrate is the preferred form of nitrogen for growing taller plants like vegetables because it is reasonably safe and is not hazardous to fish like ammonia and nitrite are. Recirculatory aquaculture systems are primarily made to raise a lot of fish in a small amount of water by cleaning the water to get rid of hazardous wastes and then using it again for fish culture (Timmons et al., 2010; Verdegem, 2013).

In an ever-growing aquaculture, aquafeed formulations, together with water consumption, represent the key factors challenging the long-term sustainability of this sector. For this reason, this highly productive sector has to move towards more sustainable practices, placing emphasis on the circular economy concept (Bunting et al., 2022; FAO, 2022). Accordingly, the present study coupled the use of a sustainable aquafeed ingredient with a sustainable culturing system. Specifically were tested during a 30 days feeding trial performed on *Lepidocephalicthys guntea*, an economically relevant freshwater fish species in rural areas of India (Llorente et al., 2020). The trial was performed in aquaponic systems, which: (i) can reduce water consumption by over 90% compared to traditional agriculture and aquaculture, growing in importance especially in areas with limited water supply; and (ii) promote the reuse of organic by-products in line with a waste-free aquaculture development, reducing the environmental impact associated with effluent discharge (Kledal, P.R. and Thorarinsdottir, 2018).

Hobbyists enjoy *Lepidocephalicthys guntea* (Hamilton, 1842) for its beautiful colour and behaviour. It is a really impressive fish. Also, it is crucial from a nutritional perspective, particularly for India's rural poor. Through the process of open water stocking or by developing a culture technique for the fish in shallow water bodies like ditches, rice fields, and aquariums, successful artificial breeding in the lab will thus help to take steps towards restoring the previous status of the biodiversity of the fish in the natural habitat. These initiatives will save the fish from extinction, and at the same time, rural residents will have the opportunity to sample the fish and have access to a source of protein for their diet (Sayeed et al., 2009). The purpose of the current study is to assess how *Lepidocephalichthys guntea*'s growth and feed utilisation in aquaponics are affected by various stocking densities of vegetable plants.

2. **Materials and methods**

2.1 Procurement of fish and vegetable plants

Fish species *Lepidocephalichthys guntea* were collected from the rivulet by overnight using bamboo wooden trap located in stream with the help of local fishermen at Majgaon village, Kawardha, Chhattisgarh. Various kind of seasonal plants such as Brinjals (*Solanum melongena L.*) Tomatoes (*Solanum lycopersicum*) and Chilies (*Capsicum annuum L.*) were collected from local vegetable garden and nursery.

2.2 **Experimental set-up**

The vertical aquaponics was designed and set-up in the Live Fish Laboratory, Department of Aquaculture at the Late Shri Punaram Nishad College of Fisheries, Kawardha (Chhattisgarh). The trial was performed in three groups of rectangular FRP tanks (250 l capacity), a control tank (without plants) (T1), an aquaponics setup tank having 15 plants (5 Brinjals, 5 Tomatoes and 5 Chilies) (T2) and an aquaponic setup with 9 plants (3 Brinjals, 3 Tomatoes and 3 Chilies) (T3). This tank has a vertical hydroponics setup on a ladder iron frame (height 57cm) supported with PVC pipe having 5-5 sacs on each step. The PVC pipes having 2.5-inch diameter were used to circulate the water in the entire system. A flexible pipe of 110 cm in length was installed to connect the fish culture tank and vertical hydroponics setup. The water from fish tank to the hydroponic unit was lifted through submersible motor pump (18watt) and the water from the hydroponics unit returned to the fish tank by gravity through S-shaped lesser PVC pipe line. The tanks were cleaned with detergent (30% chlorine) before stocking of fish and implantation of vegetable plant.

2.3 **Feeding and sampling**

The pots were prepared to implant the plants following added by vermin-compost and coconut pit. Fishes were fed at the rate of 3% of their body weight twice a day at 09:00 and 17:00 hours. A random sampling of 10 fish was carried out in 10 days intervals for the assessment of fish weight and length of plants by using a graduate ruler scale. The amount of feed given re-adjusted accordingly after each sampling.

Plate 1. Experimental set-up of aquaponics design.

2.4 **Water quality parameters**

Water quality parameters such as dissolved oxygen, pH, alkalinity and temperature were determined by using standard methods (APHA, 1995).

2.5 Growth and feed utilization parameters

The growth and feed utilization metrics such as weight gain, average daily gain (ADG), specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio and survival rate were calculated using standard formula.

$$\text{W eight gain (g)} = [\text{Final weight (g)} - \text{Initial weight (g)}]$$

$$\text{ADG (g/day)} = [\text{Final weight (g)} - \text{Initial weight (g)}]/\text{Culture period (days)}$$

$$\text{SGR (\%)} = [\ln \text{Final weight (g)} - \ln \text{Initial weight (g)}]/\text{Culture period (days)} \times 100$$

$$\text{FCR} = \text{Dry feed intake (g)}/\text{Wet weight gain (g)}$$

$$\text{PER} = \text{Wet weight gain (g)}/\text{Protein intake (g)}$$

$$\text{Survival (\%)} = \text{Final number of fish}/\text{Initial number of fish} \times 100$$

2.**6 Statistical Analysis**

All the data were expressed as mean ± SE (standard error). All the data were analysed statistically by using one-way analysis of variance (ANOVA) followed by Duncan's multiple range test were done by using SPSS software (21.0 version). The level of significance was chosen at $p<0.05$.

3. Results

3.1 Water quality parameters

Dissolved oxygen showed no significant ($p>0.05$) difference between the control and treatment groups during all the timelines. The same trend was followed by pH, alkalinity and temperature (Fig. 1).

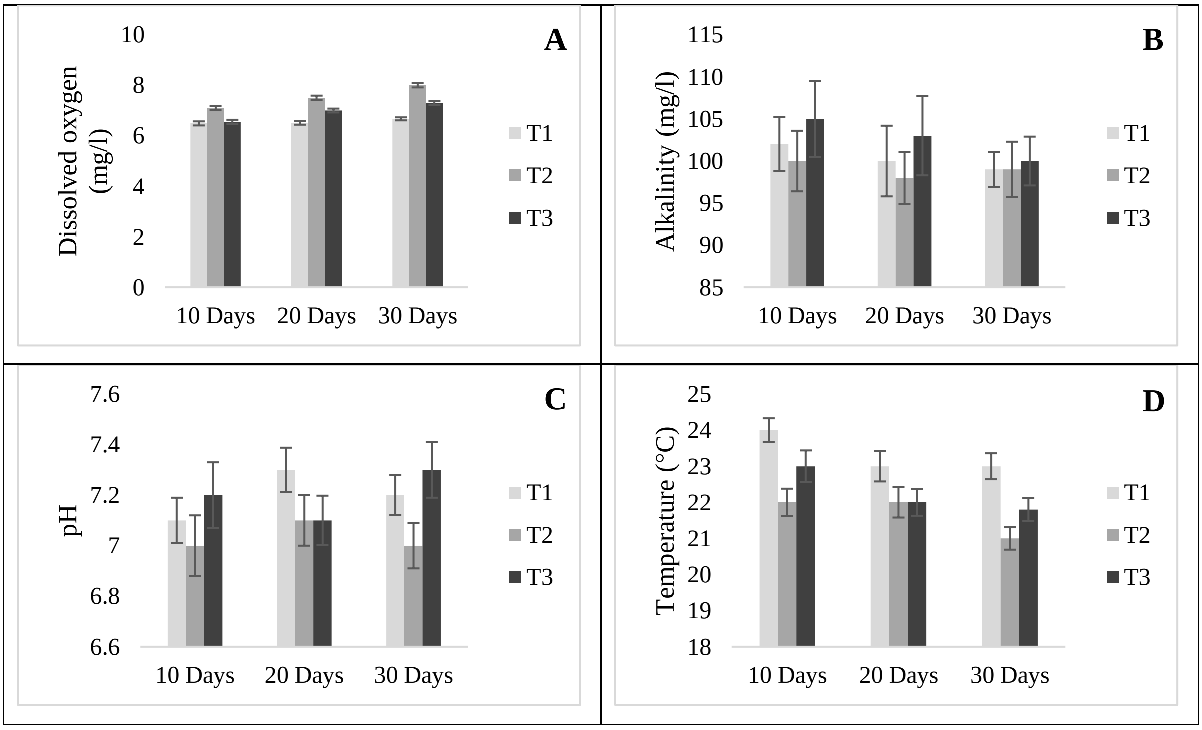

Fig. 1. Water quality parameters during feeding trial of *Lepidocephalicthys guntea* in aquaponics system.

A. Dissolved oxygen, B. Alkalinity, C. pH, D. Temperature

3.2 Growth and feed utilization parameters

Significantly ($p<0.05$) higher weight gain, specific growth rate (SGR), protein efficiency ratio (PER) and better food conversion ratio (FCR) were observed in T2. Average daily gain (ADG) showed no significant ($p>0.05$) difference between the control and treatment diets. 100% survival was recorded in all the diet groups (Fig. 2).

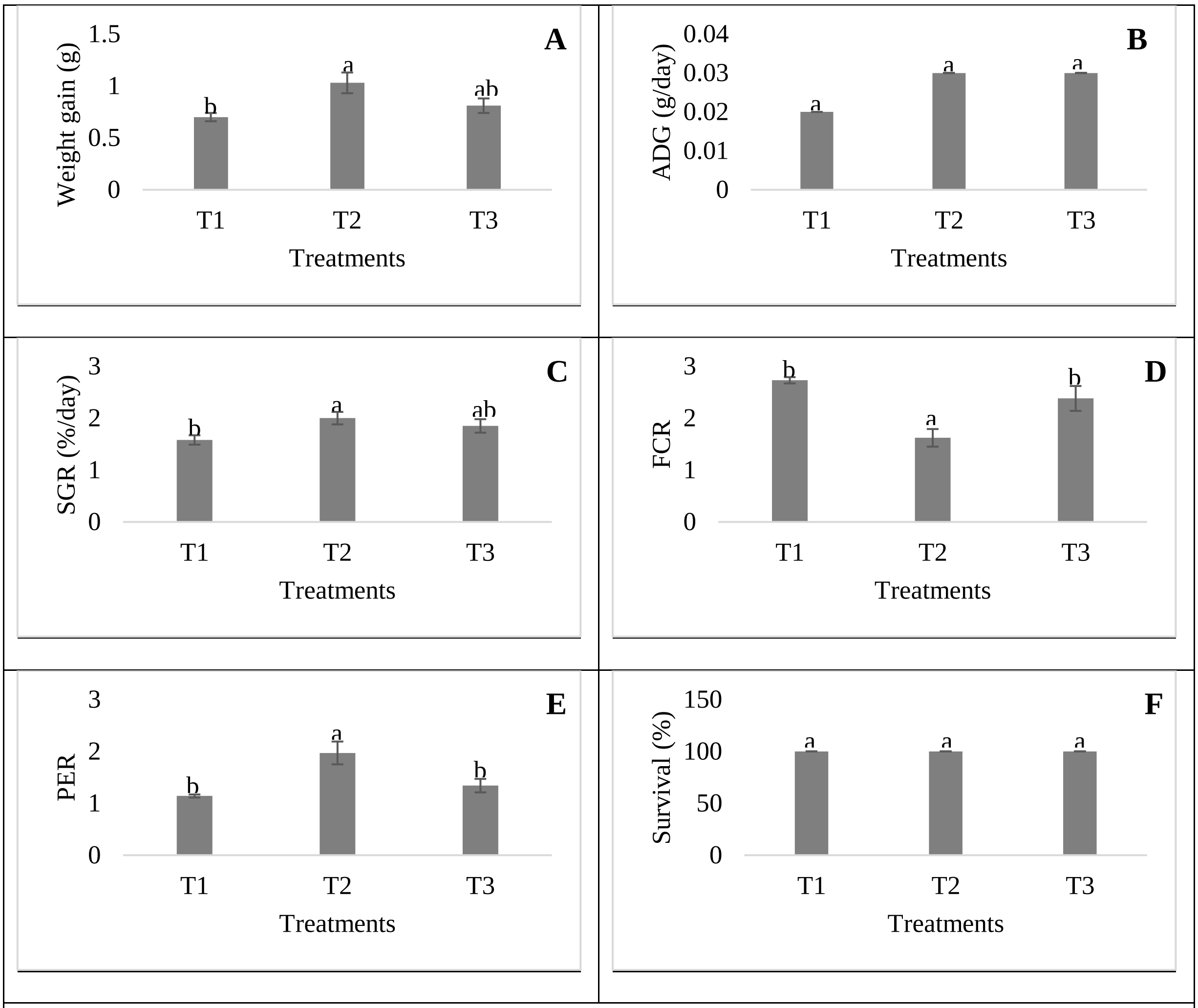

Fig. 2. Growth performances and feed utilization of *Lepidocephalichthys guntea* in aquaponics system. Results are presented as means ± SE. Means with different superscripts are significantly ($p<0.05$) different.

A. Weight gain, B. Average daily gain (ADG), C. Specific growth rate (SGR), D. Food conversion ratio (FCR), E. Protein efficiency ratio (PER), F. Survival.

3.3 Length of cultivated plants

The cultivated plant (Brinjal) exhibited a significant ($p<0.05$) difference between the different timelines in T2 and T3. Tomatoes and chilies followed the same trend (Table 1).

4. Discussion

Our goal was to investigate whether using hydroponics trays connected to fish tanks will promote *Lepidocephalicthys guntea* aquaculture without increasing environmental contamination.

Table 1. Length of different plants cultivated in aquaponics system.

Treatments/plant varieties	Initial length (cm)	Length after 10 days (cm)	Length after 20 days (cm)	Length after 30 days (cm)
T2				
Brinjal	14.2 ± 0.11^{d}	18.1 ± 0.16^{c}	20.4 ± 0.14^{b}	23.1 ± 0.22^{a}
Tomato	11.4 ± 0.12^{c}	13.5 ± 0.11^{c}	18.3 ± 0.18^{b}	21.6 ± 0.12^{a}
Chili	8.8 ± 0.14^{c}	11.2 ± 0.18^{bc}	12.5 ± 0.13^{b}	14.2 ± 0.11^{a}
T3				
Brinjal	14.7 ± 0.21^{c}	20.2 ± 0.19^{b}	22.6 ± 0.19^{ab}	25.3 ± 0.16^{a}
Tomato	11.6 ± 0.15^{d}	14.1 ± 0.10^{c}	19.3 ± 0.09^{b}	23.6 ± 0.14^{a}
Chili	9.0 ± 0.17^{d}	12.3 ± 0.21^{c}	14.2 ± 0.10^{b}	16.8 ± 0.17^{a}

Results are presented as means ± SE. Means with different superscripts in a row are significantly ($p<0.05$) different.

Aquaponics is the name of this process. By producing the secondary crop of vegetables from the same culture system, the aquaponic system increases the income from the culture operation while reducing the cost of production to some extent. The most frequent issues with water quality in recirculating aquaculture systems include the depletion of DO and the accumulation of organic matter, inorganic nitrogen, especially ammonia, and CO_2 (Rijn, 1995). These issues can only be resolved by replacing the water (Hamlin, 2006). The media bed aquaponics system used for plant culture helps plants absorb nutrients from the culture water, which reduces the need for pricey biofilters (Rakocy et al., 2006).

The aquaponics setting has been routinely studied in regard to its potential for the production of high-commercial-value crops, such as lettuce, spinach, and tomato (Tsoumalakou et al., 2023). To the best of our knowledge, aquaponics has never been tested for the cultivation of wild edible species. Nevertheless, there is a growing interest in cultivating these species, mainly by targeting the valorization of their health-promoting characteristics (Krigas et al., 2021). To this direction, it is important to develop standardized and sustainable cultivation protocols (Fanourakis et al., 2021). Aquaponics could be an efficient alternative to the current agricultural practice of adopting the fertilizer regimes applied to intensive crop farming. This latter approach except of being unsuitable for wild oligotrophic species, also has adverse impacts on product quality, as well as the commonly described negative effects of soil and groundwater quality (Kopittke et al., 2019).

The weight growth and SGR of fish in the control and treatment groups varied significantly. This demonstrates how well animals grow in systems with plants. In T2 group, the highest weight gain and SGR were likewise observed, although there was no water discharge throughout the trial period. This demonstrates the viability of incorporating this combination system into *Lepidocephalicthys guntea*'s commercial culture. Moreover, T2 had the lowest FCR, indicating that fish used feed more effectively than other treatments (Nhan et al., 2019). Based on the density of produced plants in an aquaponics system, *Lepidocephalicthys guntea*'s feeding behaviour appears to be similar to that of other species that consume food and develop through competition.

The higher efficiency of plants to use the fish waste that has accumulated in the system and has maintained the ideal water quality needed for the growth of the fish and plants during the current study may be responsible for the highest growth of fish and plants that was observed at the highest density of cultivated plants. This is consistent with the findings for goldfish (Patil et al., 2019).

5. Conclusion

This study demonstrated that the changes in culture technology of *Lepidocephalichthys guntea* in aquaponic recirculation systems were as good as in conventional systems. Aquaponic systems is provided dual profit at single-time investment. It may provide the potential to increase not only sustainability but also the production of fish and plants.

Author contributions

Pushpendra Kumar Nishad, Alka Singh, Rishabh Sharma, Surya Jaiswal and Sanjay Singh Rathore wrote the manuscript, performed the statistical analysis and were responsible for data collection and experimental designs. Dushyant Damle and Varun Mishra assisted in diet design and data interpretation. Rameshwar M. Bhosle and G. K. Dutta assisted with experimental design. All authors have read and approved the final manuscript.

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