Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 29(2): 1957 – 1971 (2025)
www.ejabf.journals.ekb.eg

Feeding Rate Influenced the Growth Performances of Tilapia, Common Carp, and Rice Yield in the Rice-Fish Integrated Farming System

Md M. Billah[1], Md Kamal Uddin[1]*, Md Yeakub Ali[2], Md Iqramul Haque[3], Md Shahjahan[3], Md Parvez Anwar[4], Shamsul Haque[5]

[1]Department of Land Management, Faculty of Agriculture, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia
[2]Institute Bioscience, Universiti Putra Malaysia, 43400, Serdang, Selangor, Malaysia
[3]Department of Fisheries Management, Faculty of Fisheries, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[4]Department of Agronomy, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh
[5]School of Agricultural, Environmental and Veterinary Sciences, Charles Sturt University Wagga Wagga, NSW 2678

***Corresponding author: mkuddin07@gmail.com**

ARTICLE INFO

Article History:
Received: Sept. 29, 2024
Accepted: Dec. 19, 2024
Online: April 8, 2025

Keywords:
Integrated rice-fish Farming,
Rice,
Feeding rate,
Growth,
Yield

ABSTRACT

The integrated rice-fish farming system is a traditional aquacultural practice that enhances resource utilization efficiency and productivity. Feeding rate is among the fundamental elements influencing fish growth in aquaculture. Hence, in a rice-fish combined culture, we evaluated the impact of feeding rate on tilapia and common carp growth and rice output. The research was carried out using nine different treatments with different triplicates. Only rice was in the control treatment (T0). In T1, T2, T3, and T4, fish were fed with traditional feed (rice bran) based on body weight of 4, 6, 8, and 10%, correspondingly. On the other hand, in T5, T6, T7, and T8, fish were fed with artificial floating feed based on body weight of 4, 6, 8, and 10%, respectively. The final body weight increased with increasing the feeding rate. The highest SGR was in the fish feed with artificial floating feed in T7 (common carp 2.40 and tilapia 4.01) and T8 (common carp 2.50 and tilapia 4.09). In T8, tilapia (306.9g) and carp (187.52 g) had the best weight gain after 75 days of transplanting. T0 produced the most rice and straw yield (5.62 and 7.00 t ha^{-1}), although the rice yield was not significantly higher than T7 (5.33 t h-1), T6 (5.25 t ha^{-1}), and T5 (5.10 t h^{-1}). The highest net return was recorded in T7 (8501.66$ ha^{-1}) and T8 (8501.16$ ha^{-1}). The T8 produced 498.44% more gross return and 58.22% more benefit cost ratio (BCR) than the control (T0). Therefore, it could be in the best interest of the farmers to adopt an 8% body weight daily feeding rate for carp and tilapia cultured in a combined rice-fish farming system.

INTRODUCTION

Rice–fish cultivating frameworks establish a novel farming system worldwide. The acquaintance of fish raising with rice production makes an incorporated agro-biological framework. The transition from rice monoculture to rice-fish cultivation is not merely a change in the agricultural system; more importantly, it represents a shift toward creating a more balanced diet (e.g., rice and fish). Ensuring the adequate supply of starch, as well as animal protein, is therefore a crucial factor for the health and well-being of farming households **(Shekar *et al*., 2015)**.

Among the cultivating system, simultaneous agrarians had a reasonable higher offer of crispy fish in their eating regimen than rotational farmers. Interestingly, the simultaneous framework farmers considered fish an optional homestead item regarding the financial return **(Halwart & Gupta, 2004)**. In cultivating structures, simultaneous rice-fish cultivating is the best nourishment supply. Therefore, expanding rice-fish cultivating could be a critical way to deal with increasing food production.

These cultivating systems influenced the rice yield and made the rice field a progressively effective biological system for rice and fish's sound and healthy production. The rate of feeding is fundamental for the development, feed change, nutrient maintenance effectiveness, and meat quality of fish **(Henken *et al.*, 1985; Hung & Lutes, 1987)**. Assurance of the nutrient necessity is likewise influenced by the feeding rate **(Talbot, 1985)**. The supply of healthfully adjusted feed is noteworthy for the development of fish, particularly during the underlying development time.

Underfeeding for youthful fish is moderately costly because of the huge concern given to a few nutrients in order to meet their development needs. Because of the high cost of their food, overfishing these fish raises their production costs and lowers water quality, which can, in the end, diminish the development of fish. In addition, it may cause the over-burden of the stomach and digestive tract to decrease the proficiency of processing and assimilation and consequently lessens feed productivity **(Jobling, 1986)**.
On the other hand, feeding less will cause debilitated wellbeing and moderate development **(Hung & Lutes, 1987; Fontaine *et al*., 1997)**. Two components, which decide the monetary feasibility of aquaculture, are the species' growth and feed usage effectiveness, and both are affected by the feeding rate **(Hung *et al*., 1993)**. Therefore, information about ideal feeding rates is significant not just for an advancing astounding weight gain and feed effectiveness and additionally for forestalling water quality disintegration as the aftereffect of an overabundance of feed.

Feeding rate and water quality are among the fundamental elements influencing fish growth **(Brett, 1979**). Therefore, deciding the perfect feeding rate is crucial to the achievement of any aquaculture activity, especially valid for fish. Since they are entirely affected by overfeeding and feed deprivation, both bring about expanded frequencies of ailment and mortality **(Goddard, 1996)**.

A few examinations observed for the impacts of feeding rate on the white sturgeon growth rate (20–40g) **(Hung & Lutes, 1987; Hung *et al*., 1993)**, the sub yearlings (250 g) **(Hung *et al.*, 1989)** and yearlings (767g) **(Hung *et al*., 1995)**. However, no such investigations were executed on the hatchlings of any sturgeon species. Along these lines, assurance of an ideal feeding rate for the development of fish is essential from both practical and biological aspects.

Most feeding rate changes rely upon fish species, size, and raising framework **(Cho *et al*., 2003)**. The feeding rate impacts the utilization of the supplements in the feed **(Mihelakakis *et al*., 2002)**. This investigation aimed to decide the best feeding rate for carp and tilapia in the rice-fish incorporated cultivating scheme.

MATERIALS AND METHODS

1. Experimental treatments and design

The research was conducted using a randomized complete block design **(Gomez, & Gomez 1984)**. There were nine treatments in total, with triplicates of each treatment. Only rice was used as a control treatment (T0). In T1, T2, T3, and T4, the fish were fed with traditional feed (rice bran; unknown proximate composition) based on body weight of 4, 6, 8, and 10%, respectively. On the other hand, T5, T6, T7, and T8 fed the fish with artificial floating feed (protein 28%, carbohydrate 20%, fat 8%, fiber 3%, ash 10%, calcium 2%, and phosphorous 1%) based on body weight of 4, 6, 8, and 10%, respectively. The stocking density for the common carp (*C. carpio*) and tilapia (*O. niloticus*) was 6 fish per square meter at a 1:1 ratio, with the amount of food provided equaling 8% of the fish's body weight. The feed was administered five days a week, twice a day, at 09:00 in the morning and 18:00 in the evening, with the total daily amount divided into two equal portions.

2. Fish's growth and yield

Random sampling was used to obtain individual fish weights from individual experimental plots **(Roy *et al.*, 1990)**. The following formulas were used to compute growth variables after 75 days:

Weight gain (g) = final weight (g) − initial weight (g)

Specific growth rate (SGR) = $$\mu = \frac{\ln(X_2) - \ln(X_1)}{t_2 - t_1}$$

Where:

Survival (%) = $$\left(\frac{\text{Final number of fish}}{\text{Initial number of fish}}\right) \times 100$$ (**Kamarudin *et al.*, 2018**).

Fish yield (kg ha^{-1}) = (Final weight − Initial weight) × Stocking density × Survival rate × Area **(Roy *et al*., 1990)**.

3. Water quality parameters

At 15-day intervals, at 08:00 and 15:00, water temperature (YSI™ 556) multi-parameter probes (USA), pH, and dissolved oxygen (DO) concentration were monitored *in situ* using a portable pH meter and a polar graphic dissolved-oxygen meter. A titrimetric approach was used to detect free CO_2 (mg L^{-1}) and total alkalinity (mg L^{-1}) using a phenolphthalein indicator of 0.0227N NaOH titrant and methyl orange indicator of 0.02N H_2SO_4 titrant, correspondingly. In addition, a spectrophotometer was used to evaluate ammonia nitrogen (mg L^{-1}) and nitrite nitrogen (mg L^{-1}) levels **(DR 1900, HACH, USA)**. All tests were carried out in accordance with the Standard Methods Handbook [18].

4. Rice's growth and yield

Plant height (cm)

Every plot's normal plant height (cm) was measured from randomly selected plants. The height of the plant was measured from the lowermost spikelet's base to the highest spikelet's tip **(Rothuis *et al*., 1998)**.

Number of total tillers per hill (total tillers·hill^{-1})

To find out the overall number of tillers per hill, all tillers from each sample were recorded, and an average was calculated. There were both effective and ineffective tillers in this group **(Lightfoot *et al*., 1992)**.

Number of effective tillers per hill (effective tillers hill^{-1})

Only the ear-bearing tillers from each sample were used to compute the number of effective tillers per hill, and the mean of the samples was determined **(Rothuis *et al*., 1998; Yamazaki *et al*., 2010)**.

Number of grains per panicle (grains panicle^{-1})

Prior to collecting samples, the number of filled and unfilled grains per panicle was recorded.

Thousand-grain weight (g)

Thousands of grains were randomly selected out of each plot, dried to a moisture level of 14%, and weighed on an electrical scale **(Rothuis *et al*., 1998; Yamazaki *et al*., 2010)**.

Grain yield (t ha^{-1})

Each field's grain production was determined by sun-drying and weighing the grains. The weight of each plot's sun-dried grains was eventually converted into t ha^{-1} **(Lightfoot *et al*., 1992)**.

Straw yield (t ha^{-1})

Each unit plot containing straw was weighed to determine the weight of the sun-dried straw. This resulted in straw output per plot, which was then turned to t ha^{-1} **(Mohanty, 2015)**.

Biological yield (t ha^{-1}), grain and straw production were combined to obtain biological production, which was estimated using the formula:

Biological yield (t ha^{-1}) = Grain yield + straw yield **(Saikia & Das, 2009)**.

Harvest index (%)

Using the given equations, the harvest index was determined using grain and biological production **(Lightfoot *et al*., 1992)**:

$$\frac{Grain\ yield}{Biological\ yield} \times 100\ \%$$

5. Statistical analysis

All the experimental data were subjected to a one-way ANOVA with SAS 9.4 at a significance level of $P < 0.05$. In addition, all the parameters were determined for mean separations using the LSD test.

RESULTS

1. Water quality parameter during the culture period

There were no significant alterations in water pH, but there was a significant increment in ammonia (0.15-0.30) and nitrogen compound (0.04-0.19), with a rise in feeding rate according to the study (Table 1). The study also found that more ammonia and nitrogen compounds were observed when feeding with artificial floating feed than traditional feed rice, 0.19 and 0.12, respectively.

Table 1. Water quality parameters of feeding rate in integrated rice-fish farming systems

Treatment	pH	Dissolved O_2 (mg/L)	Temperature (^{0}C)	Alkanity (mg/L)	Free CO_2 (ppm)	NH_3-N (mg/L)	NO_2-N (mg/L)
T0	7.20±0.19	5.60±0.08^{b}	28.19±0.72	133.00±2.81	9.04±0.97^{b}	0.15±0.02^{a}	0.04±0.01^{a}
T1	6.78±0.24	5.88±0.15^{b}	29.12±0.59	143.00±1.50	8.08±0.63^{ab}	0.22±0.02^{b}	0.08±0.00^{ab}
T2	7.10±0.64	5.50±0.01^{ab}	27.92±0.53	128.83±2.77	8.67±0.14^{ab}	0.15±0.01^{a}	0.10±0.01^{b}
T3	7.25±0.00	4.53±0.02^{a}	28.33±0.37	127.67±0.88	9.17±0.63^{b}	0.19±0.01^{ab}	0.12±0.02^{b}
T4	7.20±0.04	5.28±0.03^{ab}	28.36±0.34	131.50±1.56	10.67±0.88^{b}	0.23±0.03^{b}	0.07±0.01^{ab}
T5	7.35±0.03	4.80±0.05^{a}	28.58±0.34	129.42±0.38	7.25±0.25^{a}	0.24±0.02^{b}	0.06±0.01^{ab}
T6	7.28±0.04	5.83±0.02^{b}	29.42±0.07	121.25±1.39	6.00±0.25^{a}	0.26±0.01^{b}	0.15±0.00^{b}
T7	7.13±1.01	5.13±0.02^{ab}	28.67±0.45	132.58±1.38	11.25±0.88^{b}	0.25±0.02^{b}	0.16±0.02^{b}
T8	6.60±0.47	4.53±0.05^{a}	28.50±0.14	128.08±0.80	11.58±1.38^{b}	0.30±0.03^{b}	0.19±0.01^{b}

All data imply mean ± SD, and different letters within the same column indicate significant variation at $P \leq 0.05$.

2. Impact of feeding rate on the growth performances of tilapia and carp in the integrated rice-fish farming system

Fish survival rate was unaffected by differences in feeding rate; however, the final body weight increased with the increased feeding rate from 4-10%. The fish feed with artificial floating pellet T7 (carp 2.40, tilapia 4.01) and T8 (carp 2.50, tilapia 4.09) had the highest SGR as well as the survival. Nevertheless, T8 tilapia (306.9g) had the best weight gain over T8 carp (187.52g) at 75 days after transplanting (Table 2).

Table 2. Impact of feeding rate on the growth performances of tilapia and carp in the integrated rice-fish farming system

Treatment	Initial weight (g)		Final weight (g)		Weight gain (g)		SGR (%)		Survival rate (%)		Yield (kg ha^{-1})	
	Carp	Tilapia	Carp	Tilapia	Carp	Tilapia	Carp	Tilapia	Carp	Tilapia	Carp	Tilapia
T0	-	-	-	-	-	-	-	-	-	-	-	-
T1	25.6±0.5	12.5±0.4	142.3±2.7^{h}	143.5±3.2^{h}	116.6±2.7^{b}	130.9±3.2^{h}	1.5±1.0^{h}	1.8±1.0^{h}	86.5±2.5	87.0±4.0	1246.88	1265.98
T2	25.6±0.5	12.5±0.4	148.3±2.2^{g}	156.1±5.3^{g}	122.6±2.2^{b}	143.5±5.3^{g}	1.6±1.1^{f}	1.8±1.2^{f}	88.1±2.1	87.8±0.8	1323.49	1389.04
T3	25.6±0.5	12.5±0.4	158.5±3.0^{f}	174.6±2.0^{f}	132.8±3.0^{b}	162.1±2.0^{f}	1.7±1.3^{e}	1.9±1.1^{e}	88.9±0.9	89.0±0.6	1427.30	1576.36
T4	25.6±0.5	12.5±0.4	171.3±0.3^{e}	185.3±3.3^{e}	145.6±0.3^{b}	172.8±3.3^{e}	1.9±1.2^{d}	2.0±0.2^{d}	90.4±0.4	90.1±0.1	1569.86	1693.32
T5	25.6±0.5	12.5±0.4	188.6±2.6^{d}	292.6±2.9^{d}	162.9±2.6^{b}	280.1±2.9^{d}	2.1±1.0^{c}	2.1±1.3^{c}	90.0±0.8	93.5±0.5	1720.45	2775.64
T6	25.6±0.5	12.5±0.4	196.2±4.1^{c}	314.2±4.2^{c}	170.5±4.1^{a}	301.6±4.2^{c}	2.2±1.3^{b}	3.7±1.0^{b}	90.9±0.2	91.3±0.3	1807.56	2910.05
T7	25.6±0.5	12.5±0.4	205.4±4.6^{b}	334.2±5.0^{b}	179.7±4.6^{a}	321.7±5.0^{b}	2.4±1.1^{a}	4.0±0.3^{a}	91.7±0.7	92.7±0.1	1908.88	3143.36
T8	25.6±0.5	12.5±0.4	213.2±2.1^{a}	346.0±4.0^{a}	187.5±2.1^{a}	333.5±4.0^{a}	2.5±1.3^{a}	4.0±0.3^{a}	93.0±0.1	94.8±0.8	2009.44	3325.52

All data imply mean ± SD, and different letters within the same column indicate significant variation at $P \leq 0.05$.

3. Impact of feeding rate on the plant height of rice in the rice-fish farming system

At 75 days after transplanting (DAT), the plant height was higher in T7 (105.30cm), T0 (105.00cm), and T6 (104.7cm), while the plant's shortest height was detected in T4 (89.36cm), as shown in Table (3). However, plant height in T0 (control) was significantly higher from the beginning at 30 days after transplanting 88.34cm. However, at 45 days, even though it has the highest plant height value 89.55cm, yet they were not significantly higher than T6 (87.11cm) and T7 (87.22cm). Nevertheless, at 60 days after transplanting, almost all the treatment and the control had the same plant height except T8 (88.89cm). At 75 DAT, plant height increased 0.29% at T7, but 0.19% decreased at T6 compared to control (T0).

Table 3. Effects on the plant height (cm) of BRRI dhan49 of feeding rate with tilapia and carp in the rice-fish farming system

Treatment	Plant height (cm) at different days after transplanting			
	30 DAT	45 DAT	60 DAT	75 DAT
T0	88.34 ± 5.69^{a}	89.55 ± 6.01^{a}	94.89 ± 5.39^{a}	105.00 ± 5.00^{a}
T1	78.44 ± 4.23^{c}	83.77 ± 4.15^{c}	93.11 ± 2.71^{a}	102.20 ± 2.22^{b}
T2	78.22 ± 1.68^{c}	82.33 ± 2.85^{c}	92.00 ± 1.67^{a}	101.20 ± 1.22^{b}
T3	77.44 ± 2.50^{c}	80.78 ± 5.01^{d}	90.33 ± 3.84^{ab}	97.88 ± 3.00^{c}
T4	72.44 ± 3.95^{d}	74.00 ± 1.46^{e}	81.78 ± 2.01^{b}	89.36 ± 0.36^{d}
T5	80.11 ± 1.17^{bc}	85.44 ± 3.66^{b}	94.22 ± 3.41^{a}	103.40 ± 3.42^{ab}
T6	80.89 ± 1.90^{bc}	87.11 ± 3.08^{ab}	94.67 ± 0.88^{a}	104.80 ± 4.00^{a}
T7	82.00 ± 4.73^{b}	87.22 ± 1.50^{ab}	94.78 ± 2.01^{a}	105.30 ± 5.00^{a}
T8	74.44 ± 3.37^{cd}	77.44 ± 6.75^{d}	88.89 ± 2.79^{b}	95.48 ± 5.48^{c}

All data imply mean ± SD, and different letters within the same column indicate significant variation at $P \leq 0.05$.

4. Effects of feeding rate on the total number of tillers hill^{-1} of rice in the rice-fish farming system

At 30 days after transplanting, the number of tillers in the control T0 (9.44) and T7 (9.33 hill^{-1}) considerably improved than other treatments. However, after 45 days, it was revealed that the control was superior to all of the treatments. However, on the 75 days of transplanting, the number of tillers were recorded higher in T0 (12.31cm), T7 (11.96cm), T6 (11.33cm), and T5 (11.20cm), while T4 (9.51cm) has the minimum number of tillers hill^{-1}. At 75 days after transplantation, the total number of tillers hill^{-1} decreased 2.84% at T7 followed by 7.96% at T6 compared to control T0 (Table 4).

Table 4. Effects on the total number of tillers hill^{-1} of BRRI dhan49 of feeding rate with tilapia and carp in the rice-fish farming system

Treatment	**Number of total tillers hill^{-1} at different days after transplanting**			
	30 DAT	45 DAT	60 DAT	75 DAT
T0	9.44±0.51^{a}	11.78±0.39^{a}	11.89±0.84^{a}	12.31±0.83^{a}
T1	8.78±0.19^{c}	9.89±0.19^{cd}	10.78±0.69^{ab}	10.94±0.42^{ab}
T2	8.44±0.51^{c}	9.55±0.39^{d}	10.61±1.27^{ab}	10.78±1.07^{ab}
T3	8.33±0.58^{c}	8.89±0.19^{e}	9.77±0.69^{c}	10.11±0.19^{cd}
T4	7.22±0.77^{d}	8.44±0.39^{e}	9.11±0.19^{c}	9.51±0.72^{d}
T5	9.00±0.67^{bc}	10.00±0.33^{cd}	11.00±1.00^{a}	11.20±0.72^{a}
T6	9.11±0.19^{b}	10.44±0.20^{bc}	11.27±0.96^{a}	11.33±0.88^{a}
T7	9.33±0.34^{a}	11.00±0.50^{b}	11.56±1.26^{a}	11.96±0.93^{a}
T8	8.22±0.39^{c}	8.77±0.39^{e}	9.22±0.19^{c}	9.88±0.96^{cd}

All values represent mean ± SD, and different letters within the same column denote significant variation at $P \leq 0.05$.

5. Impact of feeding rate on the yield and yield contributing characters of rice in the rice-fish farming system

Table (5) shows that T0 had the maximum rice and straw yield (5.62 and 7.00 t ha^{-1}); although the rice production was not much higher than T7 (5.33 t h-1), T6 (5.25 t ha^{-1}), and T5(5.10 t h^{-1}), respectively. The plant height was decreased by 3.02% at T7 compared to control (T0). The greatest decrease in the number of total tillers hill^{-1} was 3.19% at T7, followed by 6.52% at T6 compared to control (T0). This finding pointed out that the application revealed a decrease of harvest index of 0.79% at T8 over the control (T0).

6. Economic evaluation of diverse stocking densities of tilapia and carp in the rice-fish farming system

Table (8) reflects the economic impact of various fish feeding rates in the rice-fish farming system. Rice-fish culture has a significantly higher net return than the control (US Dollar 807.50 ha^{-1}) while the highest net return was recorded 8501.16 \$ ha^{-1} in treatment T7. The T8 treatment produced 498.44% more advanced in gross return than the control (T0) and returned 58.22% more in benefit cost ratio (BCR) than the control (T0).

Table 5. Impact of feeding rate on the yield and yield contributing characters of BRRI dhan49 with tilapia and carp in the rice-fish farming system

Treatment	Plant height (cm)	No. of total tillers hill^{-1}	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	No. grains panicle^{-1}	No. of sterile spikelets spike^{-1}	1000 grain wt. (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T0	112.60±5.34[a]	14.12±0.88[a]	13.67±0.67[a]	0.45±0.11[e]	133.40±4.45[a]	5.50±0.50[c]	17.33±0.33[a]	5.62±0.30[a]	7.00±0.89[a]	12.62±1.13[a]	44.52±0.26[a]
T1	107.90±2.89[b]	12.33±0.33[b]	11.60±0.60[c]	0.73±0.07[c]	120.10±4.86[c]	6.62±0.62[b]	16.37±1.23[b]	4.92±0.08[b]	6.61±0.20[a]	11.53±0.28[b]	42.68±0.34[c]
T2	107.80±0.00[b]	12.05±0.05[b]	11.19±0.19[c]	0.86±0.04[b]	115.40±0.45[d]	6.79±0.20[a]	15.92±0.08[c]	4.77±0.20[b]	6.15±0.15[ab]	10.92±0.30[c]	43.67±0.88[b]
T3	106.90±2.00[b]	11.67±0.67[b]	10.76±0.20[d]	0.91±0.07[ab]	110.30±2.14[e]	6.80±0.20[a]	15.67±0.00[c]	4.60±0.20[b]	5.89±0.95[b]	10.49±0.88[c]	43.84±0.66[b]
T4	104.90±1.15[b]	9.95±0.05[c]	8.90±0.10[e]	1.05±0.13[a]	102.70±3.00[f]	7.33±0.33[a]	14.33±0.33[d]	3.61±0.30[c]	4.91±0.04[c]	8.52±0.34[e]	42.32±1.84[c]
T5	107.90±2.00[b]	12.87±0.87[b]	12.25±0.75[b]	0.62±0.08[d]	123.50±2.00[b]	6.35±0.35[b]	16.75±0.25[ab]	5.10±0.10[a]	6.80±0.10[ab]	11.90±0.17[b]	42.86±0.44[c]
T6	108.90±1.00[ab]	13.20±0.20[a]	12.61±0.10[b]	0.59±0.10[d]	125.70±5.00[b]	5.93±0.03[c]	17.00±0.50[a]	5.25±0.25[a]	6.89±0.03[a]	12.14±0.27[a]	43.23±1.12[b]
T7	109.20±1.91[ab]	13.67±0.67[a]	13.17±0.17[a]	0.50±0.07[e]	128.40±4.37[ab]	5.80±0.20[c]	17.10±0.10[a]	5.33±0.33[a]	6.93±0.07[a]	12.26±0.37[a]	43.45±1.58[b]
T8	106.50±2.05[b]	11.15±0.15[b]	10.15±0.15[d]	1.00±0.10[a]	105.30±6.67[d]	6.80±0.20[a]	14.78±1.00[d]	4.15±0.15[b]	5.25±0.45[b]	9.40±0.30[d]	44.17±2.07[a]

All values represent mean ± SD, and different letters within the same column denote significant variation at $P \leq 0.05$.

Table 6. Comparative per hectare cost and economics return of tilapia and carp with BR dhan49 yield in the integrated rice-fish farming system

Cost items	Treat. T0 ($/ha)	Treat. T1 ($/ha)	Treat. T2 ($/ha)	Treat. T3 ($/ha)	Treat. T4 ($/ha)	Treat. T5 ($/ha)	Treat. T6 ($/ha)	Treat. T7 ($/ha)	Treat. T8 ($/ha)
A : Variable cost									
1. Land preparation	1031.25	1031.25	1031.25	1031.25	1031.25	1031.25	1031.25	1031.25	1031.25
2. Rice seed	93.75	93.75	93.75	93.75	93.75	93.75	93.75	93.75	93.75
3. Seed sprouting of rice	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
4. Irrigation	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00	150.00
5. Weeding	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
6. Artificial floating fish feed	0.00	1615.01	1615.01	1615.01	1615.01	1615.01	1615.01	1615.01	1615.01
7. Rice bran	0.00	240.53	240.53	240.53	240.53	240.53	240.53	240.53	240.53
8. Tilapia fingerlings ($ 0.03/piece)	0	900	900	900	900	900	900	900	900
9. Common carp fingerlings ($ 0.06/piece)	0	1800	1800	1800	1800	1800	1800	1800	1800
10. Hired labor	0.00	162.50	162.50	162.50	162.50	162.50	162.50	162.50	162.50
11. Post-harvest operation	187.50	187.50	187.50	187.50	187.50	187.50	187.50	187.50	187.50
12. Miscellaneous	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
Sub-total of variable cost :	1637.50	6355.54	6355.54	6355.54	6355.54	6355.54	6355.54	6355.54	6355.54
B: Fixed cost									
1. Protection fence by net cover	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
2. TSP (124 kg x $ 0.37/kg)	0.00	46.50	46.50	46.50	46.50	46.50	46.50	46.50	46.50
3. Cow dung (1235 kg x $ .01/kg	0.00	15.44	15.44	15.44	15.44	15.44	15.44	15.44	15.44
4. Urea (247 kg x $ 0.25/kg)	0.00	61.75	61.75	61.75	61.75	61.75	61.75	61.75	61.75
Sub-total of fixed cost :	100.00	223.69	223.69	223.69	223.69	223.69	223.69	223.69	223.69
Total cost (A+B) :	1737.50	6579.23	6579.23	6579.23	6579.23	6579.23	6579.23	6579.23	6579.23
1. Tilapia ($. 1.85/kg)	0.00	2342.07	2569.72	2916.27	3132.65	5134.93	5383.60	5815.22	6152.22
2. Common carp ($ 3.58/kg)	0.00	4463.83	4738.09	5109.72	5620.11	6159.20	6471.05	6833.79	7193.79
Total fish income ($/ha)	0.00	6805.91	7307.82	8025.99	8752.76	11294.13	11854.65	12649.01	13346.01
1. Grain yield ($ 370.38 t^{-1})	2107.50	1845.00	1788.75	1725.00	1353.75	1912.50	1968.75	1998.75	1556.25
2. Straw yield ($ 61.73 t^{-1})	437.50	413.13	384.38	368.13	306.88	425.00	430.63	433.13	328.13
Total rice income ($/ha)	2545.00	2258.13	2173.13	2093.13	1660.63	2337.50	2399.38	2431.88	1884.38
Gross return (GR) $.	**2545.00**	**9064.03**	**9480.94**	**10119.12**	**10413.38**	**13631.63**	**14254.03**	**15080.88**	**15230.38**
Net return (NR= GR-TC) $.	807.50	2484.81	2901.72	3539.89	3834.16	7052.40	7674.80	8501.66	8501.16
Benefit cost ratio (BCR)	**1.46**	**1.38**	**1.44**	**1.54**	**1.58**	**2.07**	**2.17**	**2.29**	**2.31**

DISCUSSION

Several factors may be responsible for proper water quality management; there were no notable changes in the pH of the water and other water chemistry parameters in the present study. Dissolved oxygen, pH, and temperature were within suitable arrays for fish culture **(Aride *et al*., 2004)**. However, a considerable increase in ammonia (0.15-0.30mg/ L) and nitrogen compound (0.04-0.19mg/ L) was recorded with an increasing feeding rate. The study also found that more ammonia and nitrogen compounds were observed when feeding with artificial floating feed than traditional feed rice bran and in the dry season (*boro*) at non-significant levels (0.19mg/ L and 0.12mg/ L, respectively).

Ammonia concentrations were always below the critical levels (1 mg/L). The study also found that the abundance of plankton was significantly ($P< 0.05$) higher in T0 (74.08) and the lowest in T7 (55.75) while zooplankton highest and lowest in T4 (17.75) and T7 (11.83), respectively were also observed. The number of tillers and plant height were both influenced by the feeding rate. Plant height was higher in T7 (105.30cm), while the minimum plant height was noted in T4 (89.36cm). Plant height increased by 0.29% at T7 but decreased by 0.19% at T6 at 75 DAT compared to control (T0). However, the tiller's number was higher in T0 (12.31cm) and T7 (11.96cm), while T4 (9.51cm) exhibited the lowest number of tillers hill^{-1} at 75 days after transplanting. At 75 DAT, the number of total tillers hill^{-1}decreased by 2.84% at T7, followed by 7.96% at T6 compared.

T0 yielded the maximum rice and straw (5.62 and 7.00 t ha^{-1}, respectively); meanwhile, the yield of rice was not considerably higher than T7 (5.33 t ha^{-1}), T6 (5.25 t ha^{-1}), and T5 (5.25 t ha^{-1}) (5.10 t ha^{-1}). Fish survival was unaffected by the difference in feeding rate; however, the final body weight increases with an increase in feeding rate from 4-10%. Therefore, the fish feed with artificial floating pellet T7 (carp 2.40, tilapia 4.01) and T8 (carp 2.50, tilapia 4.09) had the highest SGR as well as the best survival rate. Nevertheless, T8 tilapia (306.9g) had the best weight gain over T8 carp (187.52g) at 75 days after transplanting.

The feeding rate for fish growth varies depending on factors such as fish species, size, and environmental conditions. The amount of food provided in each meal is a key factor influencing growth. Feeding rates at 4% body weight (BW) per day result in constrained growth **(Ng *et al.,* 2000)**. However, fish fed at higher rates, such as 8% and 10% BW/day, experienced more growth, especially when fed twice a day to maintain consistent feeding. For example, studies on cobia (Rachycentron canadum) showed that the specific growth rate (SGR) was higher when fish were fed 7% BW/day compared to 3% BW/day **(Sun *et al.,* 2006)**. This suggests that higher feeding rates lead to improved growth rates, particularly when the fish are fed regularly.

More noteworthy development was also seen in the Bagri catfish (*Mystus nemurus*), the European ocean bass (*Dicentrarchus labrax*), the channel catfish (*Ictalurus punctatus*), and pacu (*Piaractus mesopotamicus*) when encouraged with higher feeding rates instead of littler **(Robinson & Li, 1999; Ng *et al*., 2000; Eroldoğan *et al.*, 2004)**. However, the water is still within the culture condition, and it may be the reason for the good SGR and survival **(Cho *et al.*, 2003)**.

This may be because of the mutual relationship in the rice-fish integrated farming system, which allows the rice and plankton communities to make positive use of the waste from the fish, including the uneaten feed that is lacking in a normal culture system. In addition, it has accounted for the higher rice yield and fish production, and survival. Furthermore, mortalities were low and decreased with a higher feeding rate during the 75 days of this study. Similar low mortalities were reported by **Deng *et al*. (2003)**. However, a slight increase in mortality was observed in Lake Sturgeon, and Atlantic sturgeon **(Herold, 1996)**, and Siberian sturgeon **(Gisbert & Williot, 1997)**, with **Gisbert *et al.* (2000)** reporting significantly higher mortality rates.

CONCLUSION

Based on fish growth, survival rate, and rice yield, feeding at 8% and 10% of the body weight per day had the same impact. However, there was no noteworthy increase in weight gain, survival, or rice production with the higher feeding rate of 10% body weight per day. The production in treatment T7 with an 8% body weight daily feeding rate was valued at USD 8,501.66 per hectare. Given these results and considering various factors in the economic evaluation, such as feeding costs and overall production turnover, it would be in the best interest of farmers to adopt an 8% body weight daily feeding rate for carp and tilapia cultured in an integrated rice-fish farming system.

REFERENCES

APHA, AWWA. WPCF. (1985). Standard Methods for the Examination of Water and Waste Water. 16th ed. Washington, DC, USA: American Public Health Association, American Water Works Association, Water Environment Federation.

Aride, P. H. R.; Roubach, R. and Val, A. L. (2004). “Water PH in Central Amazon and Its Importance for Tambaqui (Colossoma Macropomum) Culture.” World Aquaculture., 35(2): 24—27.

Brett, J. R. (1979). Environmental factors and growth. In Fish physiology,8: 599-675. Academic press.

Cho, S. H.; Lim, Y. S.; Lee, J. H.; Lee, J. K.; Park, S. and Lee S. M. (2003). Effects of feeding rate and feeding frequency on survival, growth, and body composition of ayu post-larvae Plecoglossus altivelis. J. World Aquacult. Soc., 34(1): 85-91.

Deng, D. F.; Koshio, S.; Yokoyama, S.; Bai, S. C.; Shao, Q.; Cui, Y. and Hung S. S. (2003). Effects of feeding rate on growth performance of white sturgeon (Acipenser transmontanus) larvae. Aquaculture, 217(1-4): 589-598.

Eroldoğan, O. T.; Kumlu, M.E.T.İ.N. and Aktaş M. (2004). Optimum feeding rates for European sea bass Dicentrarchus labrax L. reared in seawater and freshwater. Aquat. 231(1-4): 501-515..

Fontaine, P.; Gardeur, J.N.; Kestemont, P. and Georges A. (1997). Influence of feeding level on growth, intraspecific weight variability and sexual growth dimorphism of Eurasian perch Perca fluviatilis L. reared in a recirculation system. Aquat. 157(1-2): 1-9.

Gisbert, E.; Williot, P. and Castelló-Orvay F. (2000). "Influence of Egg Size on Growth and Survival of Early Stages of Siberian Sturgeon (Acipenser Baeri) under Small Scale Hatchery Conditions." Aquat. 183(1–2): 83–94.

Gisbert, E. and Williot, P. (2007). "Larval Behaviour and Effect of the Timing of Initial Feeding on Growth and Survival of Siberian Sturgeon (Acipenser Baeri) Larvae under Small Scale Hatchery Production." Aquat. 156(1–2): 63–76.

Goddard, S. (1996). Feed Management in Intensive Aquaculture. Boston, MA: Springer US.

Gomez, K.A. and Gomez A. (1984). Statistical Procedure for Agricultural Research—Hand Book. New York: John Wiley and Sons.

Halwart, M. and Gupta M. V. (2004). Culture of fish in rice fields. FAO; WorldFish Center.

Henken, A.M.; Kleingeld, D.W. and Tijssen P.A.T. (1985). The effect of feeding level on apparent digestibility of dietary dry matter, crude protein and gross energy in the African catfish Clarias gariepinus (Burchell, 1822). Aquat. 51(1): 1-11.

Herold, M.A. (1996). "Lipid Nutrition in White Sturgeon (*Acipenser Transmontanus*) Larvae During Ontogeny." University of California, Davis.

Hung, S.S.; Conte, F.S. and Lutes, P.B. (1995). Optimum feeding rate of white sturgeon, Acipenser transmontanus, yearlings under commercial production conditions. J. Appl. Aquacult., 5(1): 45-51.

Hung, S. S. and Lutes P. B. (1987). Optimum feeding rate of hatchery-produced juvenile white sturgeon (Acipenser transmontanus): at 20 C. Aquat, 65(3-4): 307-317.

Hung, S.S.; Lutes, P. B.; Conte, F. S. and Storebakken T. (1989). Growth and feed efficiency of white sturgeon (*Acipenser transmontanus*) sub-yearlings at different feeding rates. Aquat 80(1-2): 147-153.

Hung, S.S.; Lutes, P. B.; Shqueir, A. A. and Conte F. S. (1993). Effect of feeding rate and water temperature on growth of juvenile white sturgeon *(Acipenser transmontanus)*. Aquat. 115(3-4): 297-303.

Jobling, M. (1986). Gastrointestinal overload—a problem with formulated feeds?. Aquat. 51(3-4), 257-263.

Kamarudin, M. S.; Sulaiman, M. A. and Ismail M. F. (2018). Effects of dietary crude fiber level on growth performance, body composition, liver glycogen and intestinal short chain fatty acids of a tropical carp (*Barbonymus gonionotus*♀ X *Hypsibarbus wetmorei* male♂). J. Environ. Biol.. 39(5): 813-820.

Lightfoot, C. L. I. V. E.; van Dam, A. N. N. E. and Costa-Pierce B. A. (1992). What's happening to the rice yields in rice-fish systems. Rice-fish research and development in Asia, 24: 177-183.

Mihelakakis, A.; Tsolkas, C. and Yoshimatsu T. (2002). Optimization of feeding rate for hatchery-produced juvenile gilthead sea bream Sparus aurata. J. World Aquat. Soc. 33(2): 169-175.

Mohanty, R. K. (2015). Effects of feed restriction on compensatory growth performance of Indian major carps in a carp–prawn polyculture system: a response to growth depression. Aquat. Nutri. 21(4): 464-473.

Ng, W. K.; Lu, K. S.; Hashim, R. and Ali A. (2000). Effects of feeding rate on growth, feed utilizationand body composition of a tropical bagrid catfish. Aquat. Int. 8: 19-29.

Robinson, E. H. and Li M. H. (1999). Effect of Dietary Protein Concentration and Feeding Rate on Weight Gain, Feed Efficiency, and Body Composition of Pond-Raised Channel Catfish *Ictalurus punctatus* 1. J. World Aquat. Soc.30(3): 311-318.

Rothuis, A. J.; Duong, L. T.; Richter, C. J. J. and Ollevier F. (1998). Polyculture of silver barb, Puntius gonionotus (Bleeker), Nile tilapia, *Oreochromis niloticus* (L.), and common carp, *Cyprinus carpio* L., in Vietnamese ricefields: feeding ecology and impact on rice and ricefield environment. Aquat. Res. 29(9): 649-660.

Rothuis, A. J.; Nhan, D. K.; Richter, C. J. J. and Ollevier F. (1998). Rice with fish culture in the semi-deep waters of the Mekong Delta, Vietnam: interaction of rice culture and fish husbandry management on fish production. Aquat. Res. 29(1): 59-66.

Roy, B.; Das, D. N. and Mukhopadhyay P. K. (1990). Rice-fish-vegetable integrated farming: towards a sustainable ecosystem. Naga, 13(4): 17-18.

Saikia, S. K. and Das D. N. (2009). Potentiality of periphyton-based aquaculture technology in rice-fish environment. J. Sci. Res., 1(3): 624-634.

Shekar, M.; Kakietek, J.; D'Alimonte, M.; Walters, D.; Rogers, H.; Eberwein, J. and Hecht R. (2016). Investing in Nutrition: The Foundation for Development–An investment framework to reach the global nutrition targets. Washington, DC: World Bank, results for development, Bill and Melinda Gates Foundation, CIFF, Thousand days.

Sun, L.; Chen, H.; Huang, L.; Wang, Z. and Yan Y. (2006). Growth and energy budget of juvenile cobia (Rachycentron canadum) relative to ration. Aquat, 257(1-4): 214-220.

Talbot, C. (1985). Laboratory methods in fish feeding and nutritional studies. In Fish energetics: new perspectives (pp. 125-154). Dordrecht: Springer Netherlands.

Yamazaki, M.; Ohtsuka, T.; Kusuoka, Y.; Maehata, M.; Obayashi, H.; Imai, K.; Shibbahara, F. and Kimura M. (2010). The impact of nigorobuna crucian carp larvae/fry stocking and rice-straw application on the community structure of aquatic organisms in Japanese rice fields. Fish. Sci.,76: 207-217.