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Relative Growth Performance of *Cyprinus carpio* and *Labeo rohita* vis-à-vis Their Improved Strains in Integrated Rice-fish Culture System at High Altitude Terraced Paddy Fields

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ABSTRACT

Background: An experimental study was conducted to examine growth performance and economic feasibility of *Cyprinus carpio* (Linnaeus, 1758) and *Labeo rohita* (Hamilton, 1822) vis-à-vis their improved strains viz. Amur carp and Jayanti rohu, in synchronously integrated rice-fish system at high altitude terraced paddy-fields (HATPF).

Methods: The experimental fields were stocked with carp fingerlings (6.95±0.67 g) at a density of 0.6 no. m^{-2} having common carp (T1), rohu (T2), Amur carp (T3) and Jayanti rohu (T4) under monoculture system, common carp+rohu (T5) and Amur carp+Jayanti rohu (T6) under polyculture. The study period was 120 days (July to November, 2022).

Result: The study recorded average weight gain of 55.72±5.58 g and 57.08±4.05 g in monoculture and polyculture systems, respectively. Amur carp performed significantly better (p<0.05) than other species/strains. Survival rate ranges from 72% to 85% with Amur carp and common carp recorded higher survival than rohu and its strain. Through integration, about 243.2 to 350 kg ha^{-1} of fish can be produced without supplementary feed and earn about Rs. 60,800 to Rs. 87,500 ha^{-1} in a single crop. Amur carp and common carp were found more suitable for rearing in integrated rice-fish culture system at HATPF.

Key words: Amur carp, Integrated farming, Improved fish strains, Terraced farming.

INTRODUCTION

Integrated rice-fish farming (IRFF) in paddy fields has been globally acclaimed as an ideal method of land use that offers one of the best means of producing both vegetable and animal proteins from the same piece of land (Halwart and Gupta, 2004). It is known to be one of the climate-resilient food-producing practices that promotes environmental integrity and sustainability with economic benefits (Ayinla, 2004). IRFF is all the more important in the Eastern Himalayan region comprising the North Eastern (NE) states of India, including Manipur where there is high demand for fish that far outweighs production but constructing fish ponds is expensive due to the hilly terrain. However, NE-India has extensive land area under rice cultivation as rice is the staple food of the region (Anonymous, 2021). Rice is cultivated even at sloppy hills by benching or terracing to impound run-off water and nutrient (Fig 1). These impounded fields retain water round the year, but, cultivate single crop of rice annually. These wet fields are rich in nutrient, micro-organism and aquatic plants and served as potential resources for rearing fish in integration with rice (either synchronous or alternate) to maximize resource utilization and crop productivity with minimum additional effort and input. Fishes with hardy nature that tolerates wide ranges of water quality fluctuation are suitable for IRFF (Halwart and Gupta, 2004). The present study chooses the selected carps based on their hardy nature, good growth rate in low input aquaculture system and their feeding nature (Basavaraju *et al.,* 2012; Mahapatra *et al.,* 2017). These fishes have potential to effectively utilise naturally available food organisms and soft aquatic plants in the fields (Chatterjee *et al*., 2004; Bera *et al.,* 2016). Thus, the present study was undertaken to assess the feasibility of rearing the selected fishes in high-altitude terraced paddy fields (HATPF) of the Eastern Himalayan region to assess the best carp species for synchronous IRFF.

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MATERIALS AND METHODS

The present study was conducted under Dr. M.G.R. Fisheries College and Research Institute, Ponneri, Tamil Nadu, for a period of 120 days (July to November 2020) at Tungjoy village of Senapati District, Manipur, India, at an altitude of 1325.96-1340.51 m above mean sea level. The experimental

HATPF (50 m^2 each) were fed by a perennial stream, dykes strengthened and enlarged (0.7 m depth and 0.5 m top width) and structured with inlet and outlet fitted with split-bamboo screens. Water depth was maintained at 0.2 to 0.4 m by adjusting inlet and outlet. A circular central refuge pond was constructed in each fields following Bera *et al*. (2016) (Fig 2). Advanced carp fingerlings (6.95±0.67 g mean weight and 5.98±0.47 cm mean total length), obtained from ICAR-Research Complex for NEH-Imphal, Manipur, was stocked in the experimental fields @ 0.6 nos. m^{-2} following Das (2018), 30-days after rice-transplantation. The 18 IRFF fields (6 treatments in triplicates) were stocked with common carp (T1), rohu (T2), Amur carp (T3) and Jayanti rohu (T4) under monoculture and common carp+rohu (T5) and Amur carp+Jayanti rohu (T6) at 1:1 ratio under polyculture system following completely randomized design (CRD). No other inputs like fertilizers/manures, lime, fish feed, *etc*. were used during the study period.

Salient physico-chemical parameters of water in the experimental fields were recorded fortnightly which includes water depth, pH, dissolved oxygen (DO), temperature and total dissolved solids (TDS) estimated using standard measuring scale, digital pH meter (pHep, HANNA, Italy), DO meter (Euktec DO, India) and TDS reader (Aquafine, India) respectively. Total alkalinity and total hardness were analysed titrimetrically following Baird *et al.* (2012). Rainfall report was obtained from Anonymous (2021) and analysed to arrive at the maximum, minimum and average precipitation levels.

Fish growth was assessed by random sampling (n=30) from each treatment field for total length (cm) and weight (g) at 30 days intervals. Growth performance of fishes were assessed in terms of weight gain percentage (WG%), daily weight gain (DWG) by following the formulae:

$$\text{WG (\%)} = \frac{\text{FW-IW}}{\text{IW}} \times 100$$

$$\text{DWG (g)} = \frac{\text{FW-IW}}{\text{No. of culture days}}$$

Where;
IW = Initial weight (g)
FW=Final weight (g).

Survival rate was recorded after final harvest using formula;

$$\text{Survival rate (\%)} = \frac{\text{Nos. of fish harvested}}{\text{Nos. stocked}} \times 100$$

Final biomass (FB) was calculated at harvest using formula;
FB (g) = [No. of fish harvested × mean body weight]

Biomass gain was calculated by deducting initial biomass from final biomass. Economic estimation followed Prasetyo *et al.* (2018) and Syaukat and Julistia (2019) methodologies with some modifications.

SPSS statistical software package was used to analyse the experimental data which were subjected to one-way ANOVA and Duncan's multiple range tests for significant differences between the means.

RESULT AND DISCUSSION

Growth and survival

The body weight gain of fish under monoculture system ranges from (T2) 50.28 g to (T3) 63.77 g (Table 1). Weight gain including WG%, DWG and biomass gain was the highest in T3 of monoculture and T6 in polyculture system which were in consonance with the report of Basavaraju *et al.* (2012) that Amur carp grows better than normal common

Fig 1: Water impounded HATPF at Tungjoy village (study area) during paddy off-season.

Fig 2: Preparation of central refuge pond and view at different growth stages of rice.

carp in aquaculture system. However, growth rate recorded (9%) in the present study was lower than that reported (30%) by the previous authors which may attribute to non-provision of external feed and high altitude impacts like low temperature and high precipitation. There was no significant difference in growth between different strains of rohu which is in contrast to the report of Mahapatra *et al*. (2017). Amur carp had significantly higher (p<0.05) growth in T3 and T6 at the end of study when compared to other treatments. Overall biomass gain was the highest for Amur carp (T3) and the least for rohu (T2) (Table 2). Rajanna *et al*. (2019) also reported that Amur carp grow faster than rohu when reared together. Common carp strains grew faster than rohu strains in both mono and polyculture systems which can be attributed to bottom-feeding nature of common carp strains and their ability to thrive well in shallow water with wide temperature fluctuations and turbidity. All the reared fishes grow better in polyculture systems than monoculture, which conforms with Wahab *et al.* (1995) who suggested that presence of common carp could positively enhance growth of other co-cultured carps.

Survival rate was the highest in T3 (85%) and the lowest in T2 (72%) as indicated in Table 2. However, differences in survival rates between normal and improved strains were negligible which is in agreement with Basavaraju *et al*. (2012). Overall survival rate in the present study was higher than that reported by Baidya and Patel (2017) in pond system which might be due to the advantages of the presence of paddy plants and good water quality aided by cascading mild flow of water through the field terraces. Common carp strains had higher survival rates than rohu strains which might be attributed to the hardy nature of the former.

Monthly growth pattern of fish

Growth rate of reared fish was uniform in all treatments in the first month of study (Fig 3) which might be attributed to rich nutrients and other field preparation processes. During initial phase, rice plants were short and thin with less tillers, allowing high sunlight exposure leading to higher abundance of plankton, aquatic vegetation and aquatic fish food organisms and subsequent good growth of fish. Islam *et al.*

Table 1: Growth performance of fish in the experimental fields.

Treatments→ / Parameters↓	Monoculture				Polyculture			
	T1	T2	T3	T4	T5		T6	
	CC	R	AC	JR	CC	R	AC	JR
Initial weight (g)	6.89^{a}±0.11	7.00^{a}±0.08	6.92^{a}±0.15	6.95^{a}±0.11	6.88^{a}±0.13	6.98^{a}±0.14	7.01^{a}±0.14	7.04^{a}±0.15
Final weight (g)	65.27^{b}±1.32	57.28^{a}±1.07	70.68^{c}±1.38	57.41^{a}±1.19	66.16^{b}±1.35	58.55^{a}±1.06	73.78^{c}±0.79	57.78^{a}±0.77
Weight gain (g)	58.38^{b}±1.41	50.28^{a}±1.51	63.77^{c}±1.12	50.46^{a}±1.23	59.27^{b}±1.81	51.56^{a}±1.22	66.76^{c}±1.10	50.74^{a}±1.14
Weight gain (%)	850.7^{b}±24	719.9^{a}±17	931.5^{cd}±35	729.9^{a}±21	867.5^{bc}±27	745.9^{a}±25	961.5^{d}±21	727.7^{a}±30
DWG (g day^{-1})	0.49^{b}±0.01	0.42^{a}±0.01	0.56^{c}±0.01	0.42^{a}±0.02	0.49^{b}±0.01	0.43^{a}±0.01	0.57^{c}±0.02	0.42^{a}±0.01

Values (Mean±SE; n=3) in the same rows with different superscripts differed significantly (p<0.05). CC-common carp; R-rohu; AC- Amur carp; JR- Jayanti rohu; DWG- Daily weight gain.

Table 2: Survival rate and biomass in the experimental fields.

Treatments→ / Parameters↓	Monoculture				Polyculture	
	T1	T2	T3	T4	T5	T6
SD (Nos. 50 m^{-2})	30.00	30.00	30.00	30.00	30.00	30.00
Survival rate (%)	83±3.3	72±5.0	853.0	75.0±5.0	80±5.0	82±5.0
Initial biomass (g)	206.97^{a}±1.50	210.00^{a}±1.50	207.90^{a}±2.11	208.50^{a}±2.00	208.05^{a}±3.20	210.87^{a}±2.23
Final biomass (g)	1631.8^{c}±30.35	1215.8^{a}±25.96	1750.1^{c}±38.43	1287.2^{a}±30.45	1506.1^{b}±25.08	1621.3^{c}±35.27
Biomass gain (g)	1424.9^{c}±26.12	1020.4^{a}±25.42	1594.5^{d}±28.20	1081.7^{a}±33.26	1298.8^{b}±21.73	1410.5^{c}±31.36

Values (Mean±SE; n=3) in the same rows with different superscripts differed significantly (p<0.05). SD-stocking density.

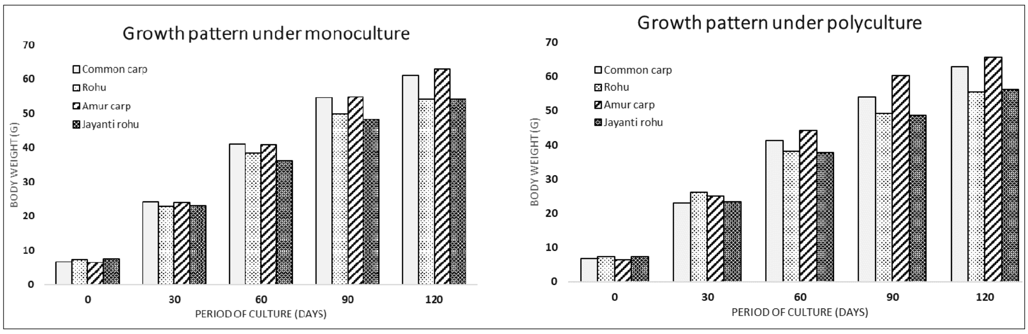

Fig 3: Monthly growth pattern of reared fish under monoculture and polyculture during the 120-days study period.

(1998) opined that fish gets more space for movement and feeding when rice plants are small and thin. So, the slower fish growth observed at the end of the study might be due to reduced temperature, taller and thicker rice plants limiting sunlight penetration, hampering phytoplankton production and hence, reduced natural fish food organisms in the system. Chatterjee *et al*. (2004) reported that fish growth at higher altitude regions could be slow due to low temperature. Moreover, as biomass (both fish and rice plants) increased, nutrient levels in soil and water of the field's diminished with more competition for food and space amongst the growing fishes as no external feed and farm inputs were provided.

Production and productivity

The fish production recorded in different treatment groups ranges from the lowest of 1.22 kg 50 m^{-2} (243.16 kg ha^{-1}) in T2 (rohu) to the highest in T3 (Amur carp) with 1.75 kg 50 m^{-2} (350.02 kg ha^{-1}) in a crop period of four months in synchronous culture with rice (Table 4) which was higher than that reported 186 kg ha^{-1} by Das (2018) stocked with common carp and fed with farm made feed. These may be due to rich plankton density in the fields of the present study due to composting during field preparation that enhances soil and water nutrients and thereby, the plankton assemblages. Other reason may also be due to frequent rainfall that brings down nutrients from upper stretches, periodically enriching the fields. Fish production from IRFF reported from across the globe ranges from as low as 37 kg ha^{-1} from Bangladesh to as high as 2,250 kg ha^{-1} from China (Kangmin, 1988; Haroon and Pittman,1997) depending on type of fish species, rearing period and methods, use of supplementary inputs and other environmental factors. The study recorded rice yields of 11.88 to 11.93 kg 50 m^{2} (2.38 to 2.39 t ha^{-1}) in IRFF fields (Table 4) which was lower than the average production of 3.51 t ha^{-1} of Manipur state

Table 3: Salient water quality parameters recorded in the experimental fields.

Treatments→ / Parameters↓	T1	T2	T3	T4	T5	T6
Water temperature (°C)	18.6±4.2	18.8±3.5	18.8±3.0	18.5±4.5	18.0±3.7	18.5±4.0
Depth (cm)	23.9±4.5	24.2±4.2	23.5±4.4	24.0±4.2	24.1±4.2	23.5±4.2
DO (mgl^{-1})	6.9±1.2	7.1±0.7	7.0±1.1	6.8±1.3	7.1±0.8	6.9±1.3
pH	7.1±0.3	7.0±0.2	6.9±0.3	7.1±0.3	6.9±0.2	7.0±0.4
Alkalinity (mgl^{-1})	52.8±1.2	53.2±1.3	53.3±1.1	53.2±1.6	52.5±1.4	53.3±1.0
Hardness (mgl^{-1})	34.4±2.1	35.0±1.9	34.1±1.2	35.2±1.2	35.5±1.9	34.1±1.2
TDS (mgl^{-1})	59.4±2.4	60.1±1.8	59.3±2.3	58.8±2.4	59.4±2.2	58.5±2.1

Values (Mean±SE; n=3); DO- Dissolved oxygen; TDS- Total dissolved solids.

Table 4: Cost estimation and economic feasibility in different treatment fields.

Component	Unit	Unit cost (Rs)	T1	T2	T3	T4	T5	T6
I. Investment								
A. Cash cost								
Rice seed	65 Kg	45.00	2925.00	2925.00	2925.00	2925.00	2925.00	2925.00
Fish seed	6000 Nos.	5.00	30000.00	30000.00	30000.00	30000.00	30000.00	30000.00
Transportation	Bulk	8000	8000.00	8000.00	8000.00	8000.00	8000.00	8000.00
Inlet/outlet sluice	40 Nos.	5.00	2000.00	2000.00	2000.00	2000.00	2000.00	2000.00
Sub-total cost	Rs.		42925.00	42925.00	42925.00	42925.00	42925.00	42925.00
B. Imputed cost								
Own/family labour	450 Manday	250.00	112500.00	112500.00	112500.00	112500.00	112500.00	112500.00
Total cost (A+B)		Rs.	155425.00	155425.00	155425.00	155425.00	155425.00	155425.00
II. Revenue generation and profit								
Rice Production	Kg/ha		2379.5	2384.5	2386.5	2375	2377	2381.5
Sale revenue	Rs/ha	45.00	107077.50	107302.50	107392.50	106875.00	106965.00	107167.50
Fish Production	Kg/ha		326.4	243.2	350	257.4	301.2	324.2
Sale revenue	Rs/ha	250.00	81600.00	60800.00	87500.00	64350.00	75300.00	81050.00
Gross Income	Rs/ha		188677.50	168102.50	194892.50	171225.00	182265.00	188217.50
Net profit	Rs/ha		33252.50	12677.50	39467.50	15800.00	26840.00	32792.50
Net profit (excluding imputed cost)	Rs/ha		145752.50	125177.50	151967.50	128300.00	139340.00	145292.50
Benefit cost ratio (BCR)			0.98	1.21	1.08	1.25	1.10	1.17

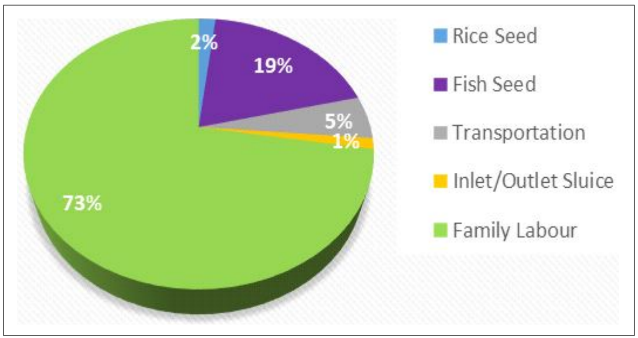

Fig 4: Component-wise investment cost break-up in IRFF fields.

(Anonymous, 2021). The low productivity in the present study may be due to non-application of fertilisers, pesticides, insecticides *etc*, as Anonymous (2021) pointed out that Senapati District (study area) falls under low productivity zone due to low usage of fertilisers. The other reason could be due to differences in rice variety, as the rice variety used for the present study was selected based on local consumer choice and stalk's ability to withstand higher water depth. Rice fields with common carp strains had slightly higher rice yield than others might be due to their burrowing and bottom-feeding nature that might have softened the soil and enhanced nutrient recirculation for uptake by rice plant (Wahab *et al.,* 1995).

Economic feasibility

The investment cost for IRFF was Rs. 1,55,425 ha^{-1} wherein procurement of fish fingerlings and transportation formed the major cost component (Fig 4). Income from sale of fish ranges from Rs. 60,800 to Rs. 87,500 ha^{-1} and rice ranges from Rs. 1,06,875 to Rs. 1,07,302 ha^{-1}. Gross income from IRFF ranges from Rs. 1,68,102 to Rs. 1,94,892 ha^{-1} with net profit of Rs. 12,677 to Rs. 39,467 ha^{-1}. Profit earning from IRFF of the present study was lower than that reported by Devi and Singh (2020) of Rs. 1,76,000 ha^{-1} from valley area of Manipur which might be due to terrain differences as rice cultivation in plain valley having lesser bunds requires lesser manpower as compared to hilly terraced fields. Based on BCR, profitability of the experimental fields was in the order of T3>T1>T6>T5>T4>T2 suggesting that IRFF with the selected carps were economically feasible. Amur carp was found to be most economically beneficial, followed by common carp under monoculture system. Singh *et al.* (2016) reported that mono-cropping of local rice variety in Manipur is non-profitable. IRFF enhances productivity of rice fields and income earning of farmers making it economically feasibility while at the same time contributes effectively to the fish production basket and nutritional security of the farmers.

Meteorology and water quality

Rice cultivation in rain-fed systems in NE-India is sensitive to precipitation as seasonal rainfall plays significant role in crop yield (Anonymous, 2021). The recorded rainfall (1627 mm) was within the yearly rainfall quantum range for Manipur state (GoM, 2014), suggesting availability of sufficient water for paddy and fish cultivation. Water temperature was dynamic as the fields were shallow and fluctuated with water depth, rainfall, sunlight exposure and other environmental conditions. HATPF had high level of DO concentrations (5.2 to 7.4 mgl^{-1}) during the study period, apparently due to continuous cascading water flow and certain perturbation of water by reared fishes. Relevant physico-chemical water quality parameters observed in the experimental fields (Table 3) were within the permissible limits for fish culture (Boyd, 1982) indicating that the ecology of HATPF in the study region is suitable for IRFF.

CONCLUSION

The present study showed that IRFF with suitable carps can considerably enhance productivity of the otherwise non-profitable single crop rice cultivation in HATPF, with minimum additional inputs and efforts. Meteorological, water quality and environmental factors of NE-India favours IRFF with selected carps in existing HATPF with no supplementary feed. IRFF can produce fish as an additional nutrient-rich food crop that can immensely contribute towards enhancing nutritional security and income for resource-poor farmers. Our study indicated that common carp and its improved strain (Amur carp) are promising species/strain for IRFF in HATPF with good survival, growth rate and production with economic benefits.

Conflict of interest: None.

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