



COMPARATIVE ECONOMIC VIABILITY ANALYSES OF INTEGRATED AND POLY CULTURE SYSTEM OF PRAWN (*MACROBRACHIUM ROSENBERGII*) PRODUCTION

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Abstract

The present study was conducted to assess the effects of integrated culture on Prawn (*Macrobrachium rosenbergii*) production compared with the prawn polyculture system, in terms of production and financial profitability and viability. In the polyculture system, prawn were incorporated with rohu (*Labeo rohita*), mola (*Amblyparyngodon mola*), snail (*Pila golubosa*), and in case of the integrated culture system with three treatments (T1, T2 and T3), prawn, rohu, mola, snail were cultured with integrating vegetables: the T1 had dike-vegetables (brinjal, lady finger, tomato); the T2 had hanging vegetable (bottle gourd; sponge gourd), and floating vegetables (*kolmi*, *belencha*); the T3 had floating-bed vegetables (tomato, onion; yardlong beans, capsicum, chili). The prawns were cultured for 240 days with feeding of commercial feed at the rate of 8% of body weight. The production of prawn in the integrated culture system was 712.34 ± 15.623 , 714.36 ± 14.77 and 741.98 ± 15.39 kg/ha whereas 646.90 ± 19.36 kg/ha prawn in the polyculture. Dike vegetable tomato, lady finger and brinjal were produced 416.67, 916.67 and 104.2kg/ha respectively; hanging vegetables guard and sponge guard were produced 666.63 and 583.43 kg/ha respectively; floating vegetables *Kolmi* and *belencha* were produced 333.3 and 625 kg/ha respectively and floating bed vegetables onion and hybrid long beans was 291 and 390 kg/ha. It has been evident that the integrated culture system had higher prawn production than had the polyculture system. The net revenue from integrated culture system was 436015.7, 411535.05 and 420018.4 TK in the T1, T2, and T3, respectively and 322837 TK in the polyculture system, addressing the profitability of integrating vegetables in the prawn multi-trophic culture system. The resultant information has pointed out the suitability of integrating prawn, finfish, snail and vegetables, which can be an eco-friendly (i.e. bio mitigation intervention) system for fulfilling household nutrition by regular consumption as well as for earning money by selling.

Keyword: Freshwater prawn, Fish, Snail, Vegetables, Multi-trophic, Aquaculture

Introduction

The ever-growing human population inhabits each and every accessible land areas in the earth, and has increasing demand for food globally (Pueppke et al., 2020, Reddy & Kishori, 2022). Since Bangladesh is a highly densely populated small country of the world, the food requirement increases proportionally to an increase in population (Ghosh et al., 2016). Therefore it is urgent to explore new technology to produce a large quantity of varieties crops (fish and vegetable, fruits) per unit area in order to fulfill the food requirement.

Bangladesh ranks as the world's fifth-largest producer of aquaculture, with a total output of about 1.85 million tons in 2012–2013. (DoF, 2014). The government of Bangladesh is promoting and intending to increase aquaculture exports, which has a positive economic impact on Bangladesh. However, the sector has faced a number of challenges, the most significant of which is the competition for land between aquaculture and agriculture. Because of continuous construction, agricultural land and water sources are becoming gradually scant; consequently, integrated agricultural systems have emerged as a practical means to guarantee productive and profitable use of land by both industries (Haque et al., 2015). To this point, the most successful methods of polyculture have involved adapting both traditional and semi-intensive farming practices. Bangladesh, a subtropical nation, has a sizable water

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supply and favorable ecological conditions for the freshwater prawn farming. The farming of giant prawn which provides food production, employment opportunities, and significant foreign exchange profits, has become one of the key ventures of Bangladesh's economy. Traditionally, farmers in coastal region of Bangladesh practice monoculture (1-2 prawn/m²) as cash crops; sometime polyculture of prawn with some carp fishes stocked (0.1/m²) and with other crops integration (Wahab et al., 2012). The prawn production ranged 500-700 kg/ha which is the production from a single piece of land (Azad, 2021). Such prawn culture system is often overlooking the trophic level of the farm; accordingly, there is possibility of un-utilization of food and feed (sometime being excess), which results in water quality deterioration ((Wahab et al., 2003; Kunda et al., 2008)) likely responsible for growth retardation and low survival in relation to stress and diseases. Apart from lower production per unit area, product-quality is also compromised due to water pollution. However, different fishes and vegetable production might be enhanced by stocking multi-layer fish species (Alim et al., 2004).

Integration of inorganic extractive species (e.g. plants) and organic extractive species (e.g. mollusc and herbivore fish) in fed aquaculture species (e.g. finfish/shrimp) system is an innovative sustainable aquaculture approach through which available resources in a piece of land can be profitably used. In addition, different trophic level can easily be considered in an integrated production system for ensuring a balanced ecosystem; multi species might be stocked with commercially important shrimp and prawn in pond and *gher*, thereby maximum layer of *gher* can be used and fish production is augmented (Chopin et al., 2012). The intensive control of many monocultures at different trophic levels within a single system is made possible by integrated aquaculture (Chopin *et al.*, 2001; Neoriet *et al.*, 2004). In an integrated aquaculture system using different trophic levels, nutrient recycling takes place; nutrients lost at higher trophic levels are resources for lower trophic level organisms to filter or absorb for further use in the growth process. Such an approach which decreases waste, boosts production, and strengthens the global food system's resilience (Hughes and Black, 2016). Troell *et al.* (2003) has implied that food scraps and other waste products from one species are gathered and used as resources for another crop species.

Over the recent years, there are a number of prawn farmers practicing integration of vegetables in the prawn *Gher*s; but they do not consider trophic level and nutrient-leach out reutilization for species selection. The present study considered these issues, and aimed at demonstrating the cost-profit comparison between the polyculture and integrated culture of prawn. Accordingly, the obtained data has addressed advantages of integrated systems in terms of product diversification and increased economic return from a unit area of land.

Materials and Method

Experimental Setup

Fifteen rectangular earthen ponds (60 m² and depth 2m) were selected for carrying out. The size and shape of the experimental ponds were same, and all the ponds had good exposure to sunlight and air. The experiment was designed with a polyculture system as a control and integrated system including three treatments T₁, T₂, T₃ (Table 1). The Control pond was stocked with prawn (as main crop), rohu, mola and snail ; the integrated system T₁ was stocked with prawn rohu, mola, snail and vegetables brinjal (*Solanum melongena*), lady finger (*Abelmoschus esculentus*) and tomato (*Solanum lycopersicum*) on dike and floating vegetables *kolmi* (*Ipomea aquatica*) and *helencha* (*Enhydra fluctuans lour*); the ponds of the T₂ system was stocked with prawn, rohu, mola, snail, floating vegetables *kolmi* and *helencha* and hanging vegetables bottle gourd (*Lagenaria siceraria*) and sponge gourd (*Luffa cylindrica*); the ponds of the T₃ system was stocked with prawn, rohu, mola, snail and floating bed vegetables tomato, onion (*Allium cepa*), yardlong beans(*Vigna unguiculata*), capsicum (*Capsicum annum*) and chili(*Capsicum annum*).

Table 1. Experimental design showing control and three treatments with three replications.

Culture System	Treatment	Prawn+rohu+mola+snail	Dike + floating vegetable	Hanging + floating vegetable	Floating bed vegetable
Poly culture	Control	+	-	-	-
Integrated culture	T ₁	+	+	-	-
	T ₂	+	-	+	-
	T ₃	+	-	-	+
		Replication 3	Replication 3	Replication 3	Replication 3

Pond preparation

At the start, the ponds were dewatered entirely. Any unwanted organisms such as weeds, small fishes, and other vegetation were eliminated. The ponds were restored by removing excess mud at bottom and repairing broken and uneven dikes. Then, the ponds were limed (CaCO_3 ; 300 kg ha^{-1}) for keeping pH level suitable for fish rearing, and fertilized using compost at 720 kg ha^{-1} . Thereafter, upto a depth of 2m, the experimental ponds were watered using deep tube-well water through a plastic pipe. During the experiment, fertilizers: Urea, TSP, molasses, and yeast were also used in the ponds for enriching primary productivity. Temporary shelter with an area of 1.2 m^2 for snails were prepared by embedding a number of bamboo split of 1.2 m long into the bottom at 45° angle and setting out in a square array of three lines in each pond; each bamboo split.

Collection and stocking of prawn PL, rohu and snail seed

Post-larvae of prawn (PL_{10}) were collected from Bangladesh Fisheries Research Institute (BFRI), Bagerhat in a plastic polybag and released them in the nursery pond after proper acclimatization. After 45 days of nursing, the juvenile prawns (3.1-3.18 g) were stocked in the experimental ponds. Fingerlings of the rohu (120-130 g) were bought from a fish hatchery and were transported in continuously aerated plastic drums to the pond site. Before releasing into the ponds, acclimatization of the fishes to the environment of the research ponds were done by keeping them in hapa nets. According to Wahab et al., (2012) and Haque et al. (2014), the prawn-PLs and rohu fingerling were stocked at the rate of $20,000 \text{ ha}^{-1}$ and 1000 ha^{-1} in the ponds. Mola and snails were collected from nature, and $2500 \text{ snail ha}^{-1}$ (kibria et al (2018) and $1000 \text{ mola ha}^{-1}$ (Haque et al., 2014) were stocked in each pond.

Aquatic plant cultivation on floating trays

Brinjal, tomato and lady finger seeds were sowed in the dike of ponds; 5-7 seeds were sown 3.0 m apart across the embankment of T1 ponds. Bottle gourd (*Lagenariasiceraria*) and sponge gourd seeds were sowed and hanging stage using bamboo and a net surrounding the dike of the T2 ponds were made; 3-5 seeds were sown 2.0 m apart in a pit of 3.0 cm depth in all parts of the pond-dikes. *Kolmi* and helencha seeds were sowed in the corner of the dike and floated in the pond water. Tomato, onion, yardlong beans, capsicum and chili were sowed in the floating beds on trays made of iron and supported with empty plastic bottles, being placed in the T3 ponds. Twenty eight cuttings (average length 16 cm each) of each floating vegetable were planted in six clusters in each tray containing nine cages made of iron bar frames and a synthetic nylon net (mesh size 2 cm) placed on the bottom; a substrate of 2 cm layer bottom mud from the same pond was used for transplanting vegetables.

Feeding

Commercial prawn feed (quality feed starter crumble, 32% protein level) was given twice a day, in the morning (08:00 am and 17:00 pm) at the rate of 8% of body weight. Once prawns weight was above 10 g , grower feed containing 30% protein was given at the rate of 8% body weight.

Sampling

Sampling of prawn and rohu was done in each 15 days interval with the cast net; 10 % of the stock was sampled each time and weight was recorded for further analysis.

Harvesting and yield estimation

At the end of the investigation, the fishes were harvested by drying the ponds completely. Species-wise fishes were counted, and each individual fish was weighed using an electronic balance. Weight gain%, specific growth rate (SGR; % per day), food conversion ratio (FCR), and total production of fishes were calculated following the formulae as shown below:

Weight gain = (Average final weight – Average initial weight)/Average initial weight

$\text{SGR (\% day}^{-1}\text{)} = ((\ln \text{ final weight} - \ln \text{ initial weight})/\text{Duration of the experiment (days)}) \times 100$

$\text{FCR} = \text{Feed applied (dry weight)}/\text{Live weight gain (wet weight)}$

$\text{Gross yield} = \text{Total number of fish at harvest} \times \text{average final weight}$

Snails were harvested from the pond bottom using a harvesting apparatus, and then counted by pieces. Vegetables were harvested at 30-day intervals (Salam and Roy, 2012), and gross yield was estimated.

Gross yield=Partial harvest + Final harvest

Data analysis

Microsoft Excel and SPSS version 26 software packages were used to represent and analyze the collected data. Statistical analyses one-way ANOVA and multiple regression were performed using SPSS (version 26.0); 5% level of significance was used for each analysis. Tukey HSD was applied to conduct multiple comparisons for assessing significant differences.

Results

After eight months culture period, the harvested prawns of the polyculture system had weight in the range of 32.01-36.12g, while the final weight of the prawns ranged between 35.12 and 39.04g for the T₁ system, 35.76 and 38.87g for the T₂ and 36.45 and 40.46 for the T₃ system, respectively (Table 2). The highest weight gain and SGR was recorded in the T₃ system, while the lowest weight gain and SGR were found in the prawns from the polyculture system. The T₃ had also the lowest FCR while the highest FCR was estimated for the polyculture system. There was significant ($p < 0.05$) variation in final weight, weight gain, SGR and FCR between the polyculture and integrated system; but, no significant ($p \geq 0.05$) variation in these estimators was found among the integrated treatments. Regarding survival, the T₃ system had the highest live prawns; however, no significant ($p \geq 0.05$) variation among the systems was observed.

The harvested rohu of the polyculture system had weight in the range of 607.3-621.3g, while the weight of the rohu ranged between 622.7 and 645.4g for the T₁ system, 613.5 and 633.8g for the T₂ and 601.2 and 633.1g for the T₃ system, respectively. The highest weight gain and SGR was observed in the integrated system T₁, and the lowest weight gain and SGR for the T₃; but there was no significant ($p \geq 0.05$) variation in these estimators among the systems. The integrated system T₁ had the utmost survival and the polyculture system had the least survival; the survival did not vary significantly ($p \geq 0.05$) among the culture systems.

Table2. Production performance of the polyculture and integrated systems.

Species	Parameters	Experimental treatments			
		C	T ₁	T ₂	T ₃
Prawn	Initial Weight (g)	3.13	3.13	3.13	3.13
	Final Weight (g)	33.86±5.22 ^a	37.25±7.44 ^b	37.39±5.37 ^b	38.6±3.27 ^b
	Weight Gain (g)	30.93±5.32 ^a	37.07±3.85 ^b	37.28435±3.89 ^b	37.00232±5.37 ^b
	(%) SGR	1.45±0.07 ^a	1.02±0.04 ^b	1.43±0.07 ^c	1.49±0.08 ^b
	FCR	1.5±0.3 ^a	1.36±0.2 ^b	1.35±0.17 ^b	1.38±0.3 ^b
	Survival rate (%)	95.52±0.3 ^a	95.63±0.19 ^a	95.24±0.34 ^a	96.14±0.4 ^a
	Gross Production (kg/ha)	646.90±19.36	712.34±15.62	714.36±14.77	741.98±15.39
Rohu	Initial Weight (g)	115.35±2.57 ^a	115.35±2.57 ^a	115.35±2.57 ^a	115.35±2.57 ^a
	Final Weight (g)	636.72±3.70 ^a	646.28±5.36 ^a	646.64±5.91 ^a	657.26±7.61 ^a
	Weight Gain (g)	632.45±1.45 ^a	642.01±1.37 ^a	642.37±1.83 ^a	652.99±1.77 ^a
	(%) SGR	2.61±0.03 ^a	2.62±0.02 ^a	2.62±0.02 ^a	2.62±0.02 ^a
	Survival rate (%)	84.37±0.49 ^a	86.40±0.98 ^a	84.62±1.32 ^a	84.82±1.48 ^a
	Gross Production (kg/ha)	520.18±4.21	547.35±5.45	531.35±10.97	525.09±14.21
Mola	Gross Production (kg/ha)	95.31±1.17	103.7±0.57	98.23±0.21	104.36±0.31
Snail	Gross Production (kg/ha)	123.24±0.23	125.74±1.36	119.99±0.3	128.23±0.25
Vegetables	Gross Production (kg/ha)	-	1731.9±29.02	1852.5±10.03	578.3±1.79

Different superscript letters in the same row represent significant differences ($p < 0.05$) among the treatments

Regarding production, the polyculture system had production in the range of 607.56-689.21 kg prawn/ha and 512.74-530.32 kg rohu/ha. In case of integrated system, 675.12-745.27 kg prawn/ha, 535.12-560.43 kg rohu/ha, 100.7-104.2 kg mola/ha, 122.32- 127.34kg snail/ha and 1550-1800 kg vegetables/ha were recorded for the T₁; 681.87-745.43kg prawn/ha, 516.07-558.34 kg rohu/ha, 96.73- 99.87kg mola/ha, 117.85-121.54 kg snail/ha and 1650.73-1900.43 kg vegetables/ha for the T₂; 706.32-750.18 kg prawn/ha, 488.89-542.94 kg rohu/ha, 102.76-106.32 kg mola/ha, 125.63-127.54 kg snail/ha and 950.32-1250.12 kg vegetables/ha for the T₃ system. There was

significant ($p < 0.05$) difference in total crop production between the polyculture and the integrated system. The return analysis has shown that there was significant ($p < 0.05$) difference in gross return and net income between the polyculture and integrated, and among the integrated treatments as well (Table 3). The highest net income was estimated (BDT 436015.7±410.55) for the T1 system while the lowest (BDT 322837) was for the polyculture system.

Table 3. Economic analysis of the polyculture and integrated system production. Total expenditure and net profit shown in Bangladeshi currency (BDT).

Items	Control	T1	T2	T3
A. Capital cost (CC)				
Mud excavation & dike repair	25000	25000	25000	25000
Labour cost	40000	40000	40000	40000
Nylon net & bamboo	15000	15000	15000	15000
Total capital cost (CC)	80000	80000	80000	80000
B. Operating costs (OC)				
Lime	15250	15250	15250	15250
Fertilizer (Urea, TSP)	6000	6000	6000	6000
Molasses	900	900	900	900
Yeast	1400	1400	1400	1400
Prawn PL	30000	30000	30000	30000
Rohu	10000	10000	10000	10000
Brood Mola	1800	1800	1800	1800
Snail	5000	5000	5000	5000
Vegetable		2250	2257	1500
2.3 Feed (Kg)	52450	52450	52450	52450
2.4 Harvesting cost	15000	15000	15000	15000
2.5 Miscellaneous	10000	10000	10000	10000
Total Operating cost (OC)	147800	150050	150057	149300
C. Total Cost = CC+OC				
	227800	230050	230057	229300
D. Gross Income				
Prawn	388128±627.9	427348±521.12	428806±278.31	436906.3±1212.29
2.2 Rohu	140871±610.37	147784±388.54	141466±526.78	144101±465.45
2.3 Mola	16938.14±111.2	16938.14±110.32	16741.52±102.33	18535.92±97.34
2.4 snail	4700.23±14.43	4282.43±14.11	4579.7±13.67	4765.05±14.21
2.5 vegetable		69713.9±29.69	50000±51.85	47010±31.34
Total gross	550637.03±1565.76 ^a	666065.9±410.55 ^b	641592.4±29.12 ^c	649318.5±424.16 ^d
Net income D-C	322837±1565.76 ^a	436015.7±410.55 ^b	411535.5±293.12 ^c	420018.4±424.16 ^d

Different superscript letters in the same row represent significant differences ($p < 0.05$) among the treatments

Discussion

Integrated aquaculture has a significant contribution into the livelihoods as well as socioeconomic development of rural communities in many Asian countries (Nair et al., 2012, Tran et al., 2020); more specifically, integrating cultivation of different crops in a single unit has remarkable advantageous; it facilitates multiple crop production with maintaining fertility, lessening fertilization-cost, reducing waste accrual, aiding pest control, thereby plays role in generating additional income means for the farmers. This study results showed that the total production of different integrated culture system was higher than that of the polyculture; the production of the polyculture system 1385.87±19.12 kg/ha in this study was similar to the previous studies; Ahsan et al (2013) reported 1484±8 kg/ha production from the freshwater prawn-carp-mola polyculture system. While, the production of the integrated system was similar to the production from the integrated prawn ponds (Huq et al., 2009). This study demonstrated that the lowest production was recorded in the polyculture system, and thus the gross and net-income were found higher in the integrated system. Haque et al. (2012) reported greater monetary returns from fish-vegetable integrated culture

system. Among the integrated ponds, the net income from the T1 system was higher in relation to the comparatively good fish and vegetable production of different species of which selling price was relatively higher in the market.

Accordingly, previous studies have reported how farmers get benefits thorough producing substantial amount of rice, fish and vegetables for their consumption and sales, which directly affects the expenses and income patterns of the farmers' family (Marques, 2016; Belton, 2016). It has been very evident from the present study that the integrated culture system was more profitable than a polyculture system; Prawns, rohu, mola, snail and vegetables can be cultured throughout the year. The data of this study have suggested that farmers can grow vegetables on the *gher* embankment by dike and hanging and the floating and floating bed system on the surface of the water in an integrated system. Bottle gourd, sponge gourd, brinjal, lady finger and tomato seed can be sown along with transplanted *kolmi* and *helencha*, which will increase household income and food production and reduce nutritional deficiency. Moreover, an integrated culture system creates an earning opportunity of additional income which can be obtained from a single piece of land compared to a polyculture. Integrating vegetables and aquatic plants in finfish and shellfish cultivation techniques i.e. prawn-carp-sanil-aquatic plants-dike-vegetables farming systems dispense various benefits including various food supply, livelihood support and ecological refinement.

Conclusion

This study has demonstrated that integrating different fish, snail and vegetables in the prawn production ponds were economically profitable over the system wherein prawns were only cultured with fish and snails. In the integrated system, prawns can be considered as the main crop, while carp, mola snail and vegetables maintain cash-flow with production and sales throughout the year. Different types of short-cycle vegetables can be grown on dikes, hanging and floating along with fishes in a given year. This study has suggested that integrating dike, hanging and floating vegetables in the prawn multi-trophic culture system may have contribution to greater production of various foods and thus, higher earnings of the farmers from a single piece of land.

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Conflict of Interest

The authors declare no conflict of interest.

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