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Article

Scaling up of tigershrimp (*Penaeus monodon*) production in brackishwater pond under diversified cropping regimes

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Abstract: To develop a scientific and affordable shrimp farming system for marginal to medium farmers with low inputs and higher returns by scaling up of production per unit area, shrimp culture was practiced with 3, 5 and 7/m^2 stocking densities for the period of 60 days as short cycle and 120 days as long cycle**.** All the hydrographical parameters were found congenial in different treatments except dissolved oxygen (DO) in case of higher stocking density and long culture pattern. However, the specific growth rate (SGR) was optimal in both culture cycle but increased sharply in first 3-4 weeks of grow out period. Distinct survival rate were found in different treatment which was ranged from 86.39 to 90.96% but did not show significant difference (P>0.05%) among the treatments of short and long culture cycle. Total yield was ranged from 990 kg/ha to 1998 kg/ha for short cycled double and 1012 kg/ha to 2032 kg/ha for single cropping pattern. Highest production was obtained under the stocking densities of 7/m^{2}although the average production showed significant difference (P<0.05%) among the treatments of both culture patterns. The food conversion ratio (FCR) value seems similar for all cropping patterns and ranged between 1.15 and 1.57. Except stocking density of 7/m^2 at short cycle culture, net benefit were significantly (P>0.05%) higher in long cycle crop than that of aggregate of two short cycle crops. But benefit cost ratio (BCR) in short culture cycle is significantly (P>0.05%) higher than that of long culture (120 days) which indicates higher net benefit as well as positive feasibility of short culture system. Considering the infrastructural facilities in farm level and resource capability, this shrimp farming technology would be appropriate to boost up the production and income particularly for marginal to medium farmers.

Keywords: diversified cropping; tiger shrimp; production; brackishwater; growth; production; cost; return

1. Introduction

Currently brackish water shrimp farming in Bangladesh is one of the most vainglorious sectors in terms of receiving an attention to earn huge amount substantial revenues and foreign currency to boost up national economy. The black tiger shrimp (*Penaeus monodon*) is the most widely cultured species in the brackishwater aquaculture of Bangladesh. The future of steadily expanding shrimp farming industry is largely dependent on the sustainable increment of unit area production. Bangladesh produced 2,23,582 MT shrimp/prawn in the year 2014-15 with an average production rate of 811 Kg/ hectare for all types of farming systems (DoF, 2016, National Fish Week-Bengali Compendium). But in the traditional or extensive method, on average 300 Kg/ha can be produced (The Daily Star, 2015) which is not sufficient enough that means we have to increase our per hectare production. The productivity of shrimp in other shrimp producing nations is much higher that is 4000 kg/ha in Australia, 2500 kg/ha in Thailand, 1500 kg/ha in Malaysia and 670 kg/ha in Philippines respectively as both of the country brought 60 percent of their farms under semi-intensive culture system (Rahman *et al*., 2013). Of the total shrimp farming area (2, 75,583 ha) of Bangladesh, only around 2,500-3,000 hectare area is being used under modern/scientific shrimp farming technology like semi-intensive method. From this figure we can surmise that a larger area of coastal impoundments can’t be used effectively and remain underutilized in regard to rate of production. Similarly sudden disease outbreak is frequently disrupting our whole shrimp farming industry. Bangladesh Fisheries Research Institute (BFRI) have developed culture technology of shrimp with the provision of prevention of viral disease (Saha and Alam, 2008) which entails large amount of investment. However, most of the farmers still follow the traditional method due to having poor resources because modern and scientific culture technique is more cost effective and marginal to medium farmers are very reluctant to adopt scientific interventions of culture management for increasing production (Saha *et al*., 2016).

It is evident that we have enough scope to increase our total yield more by minimal intensification which is affordable by the marginal and medium farmers. Introduction of some technological interventions through diversified cropping system followed by modification in *gher* area, culture period, stocking density and other inputs would surely up rise production as well as profitability. Diversified cropping regime is a lower investment related culture system followed by modification in *gher* (pond) size, culture period, stocking density and other inputs that would surely up rise production as well as profitability. If traditional shrimp farmers can be technically efficient and impetuously accustomed with diversified cropping pattern ensuring lower management cost with higher production rate Bangladesh could successfully ensure a sustainable production in near future up to maximum level. Although, a great deal of research work have been conducted regarding stocking, growth, survival and production of (Washim *et al*., 2016; Hossain *et al*., 2013; Debnath *et al*., 2013; Latif and Alam, 2008; Gunarto *et al*., 2006; Saha *et al*., 2006 and Abu Hena *et al*., 2004), but no or limited publications have been addressed the diversified cropping system of shrimp farming. In this backdrop, the present study attempts to investigate the feasibility of the production behavior and profitability of the diversified shrimp farming operation focusing variation in culture period (short term-60 days & long term-120 days) with different stocking densities in the southwest shrimp farming region of Bangladesh.

2. Materials and Methods

2.1. Site of the experiment

The experiment was carried out during May to August, 2016 at the Brackishwater Station of Bangladesh Fisheries Research Institute, Paikgacha, Khulna. Eighteen on-station earthen ponds having an average area of 0.1 ha each in the pond complex were selected for the study. The experiment covered a period of 120 days.

2.2. Experimental design

The experiment was designed with six treatments each with three replication *viz.* treatment T_1 and T_2 covered short (60 days) term and long (120 days) term culture period respectively with stocking density of 3 no/m^2. Similarly treatment T_3 and T_4 covered the same culture period with stocking density of 5 no/m^2 and treatment T_5 and T_6 also covered the same culture period with stocking density of 7 no/m^2.

2.3. Pond preparation and pre-stocking management

Initially ponds were completely drained out and re-excavated to remove the fouled layer of pond bottom and allowed to sun dry for 7-10 days to increase the oxidation capacity of hydrogen sulphide and to eliminate other obnoxious gases.

For short term (10-15 days) nursing of shrimp post larvae in-pond nursery, about 10% area of each pond receiving the respective treatments was enclosed with nylon net fastened with bamboo frame. The entire ponds area was fenced by blue net as biosecurity to prevent entering virus carrier species. Soil liming was done with agricultural lime and dolomite (3:1 ratio) @250 kg/ha. The ponds were filled with tidal water up to a depth of 1.0 m by filtration with small mesh size filter net and then treated with chlorine @ 20 ppm to disinfect water and kill all animalcules. Organic fertilizers, such as fermented mixtures of molasses, rice bran and yeast were spread across the ponds at a ratio given in Table 2. After 2-3 days of molasses application mustard oil-cake were applied as liquid state @ 60 kg/ha. Then the ponds were fertilized with urea and TSP @ 25 and 30 kg/ha, respectively for quick development of colour of water and production of plankton. However, major inputs applied in this experiment are furnished at a glance in Table 1.

Table 1. Major interventions followed in the experimental ponds.

Key features	Doses/application
Liming of soil	250 Kg/ha (Quick lime: dolomite 3:1)
Chlorination	@ 20 ppm
Urea+TSP	25+30 (Kg/ha)
Fermented Molasses mixture (Molasses: rice bran: yeast)	140:35:0.60 kg/ha.
PL (Post Larvae)	PCR tested PL
In-pond nursing	15 days
Dolomite (water)	@ 15 ppm (Monthly basis)
Feed	CP feed
Pond depth	1 Meter (Minimum)
Zeolite	@ 4 ppm (3rd & 4th month of culture)

2.4. Post stocking management

After fertilization PCR tested post larvae (PL_{15}) were procured exclusively from commercial hatchery and acclimatized with the pond water and stocked slowlyas per mentioned design to the in-pond nursery during the late evening period. In the nursery the stocked PL were fed with CP nursery feed manufactured by India. After two week of nursery rearing, the juveniles were released to the whole pond by up-folding the nylon net of the nursery enclosure. In the grow-out ponds, the shrimp were fed with good quality commercial feed *eg*. CP feed depending on the biomass of shrimp. Growth of fishes was monitored at weekly interval and feeds were adjusted according to CP feed manual. The feeding frequency was 4 times per day as in the morning at 6.00 a.m., 11.00 a.m., 6.00 p.m. and 10.00 p.m. respectively. The ingredient of the feed includes Fish meal, Wheat flour, Soybean meal, Fish oil, Phospholipid, Vitamins and Minerals etc. The composition of CP feed applied in the culture ponds are given below in Table 2.

Table 2. Composition of CP feed applied during the culture period.

Composition	Percentage
Crude protein	38 (Minimum)
Fat	5 (Minimum)
Moisture	12 (Maximum)
Fibre	4 (Maximum)

Aeration was provided to the ponds whenever necessary through agitating water by paddle wheel/airjet but no aeration was applied in short culture ponds. As post stocking management, all ponds were limed @ 6–8 ppm with an equal mixture of $CaCO_3$ and $CaMg(CO_3)_2$, fortnightly during the entire culture period. Additional liming (dolomite) was also done at the same rate after every heavy rainfall. Sampling was done in the pond every week during early hours of the day with cast net for checking the healthiness and growth rates.

2.5. Monitoring of water quality

During the grow out period the pond ecological variables *viz*., temperature, depth, transparency, salinity, pH and total alkalinity were monitored and determined at weekly interval following standard methods as mentioned by (APHA, 1992). Dissolved oxygen (DO) was monitored almost daily after 50 days of culture (DOC) in long culture system.

2.6. Harvesting and data analysis

After 60 days of culture, shrimps of all short cycle ponds (1st crop) were harvested by complete dewatering and the ponds were prepared again for 2nd short cycle following all the previous interventions. After completion of grow-out period both in short and long culture pattern all the shrimp were harvested successfully by complete dewatering. Then growth, survival and production were estimated. ANOVA and DMRT was done to observe differences in growth, survival rate, yield, FCR values and economic returns within the treatments of short and long cycle culture pattern and the level of significance were considered at the 5% (P>0.05). Data was compiled and analyzed using software MS Excel and SPSS (Statistical Package for Social Science) version-20. The FCR (Food Conversion Ratio) and specific growth rate (SGR%) was estimated following the formula given below.

$$FCR = \frac{\text{Amount of dry food (g)}}{\text{Live weight gain (g)}}$$

$$SGR\ \% = \frac{\ln \text{Final weight (g)} - \ln \text{Initial weight (g)}}{\text{Number of culture days}} \times 100$$

3. Results and Discussion

3.1. Assessment of hydrographical parameters

The different physico-chemical parameters of the pond water under short and long culture patterns are presented in Table 3. All the hydrographical parameters varied minimally in different treatments except dissolved oxygen (DO) and salinity. Maintenance of good water quality is of great importance for optimum growth and survival of shrimps (Soundarapandian *et al.*, 2010). The growth and survival of shrimps are affected by temperature, salinity and dissolved oxygen concentration suggested by (Subrahmanyam, 1973; Verghese *et al.*, 1975 and Liao, 1977). However the water temperature values were varied between 29^0 C and 33^0 C in all the ponds and were slightly higher than the suitable range for growth of shrimp reported by (Boyd and Fast, 1992). Salinity is one of the most important ecological factors which affect the growth and survival of *P. monodon* (Chakroborti *et al.*, 1986). In the present study salinity was found between 6.5-17 ppt during the culture period which complies with the report of (Predalumpaburt and Chaiyakam, 1994), where they recommended salinity ranging from 5.0-32.0 ppt is favourable for shrimp culture. The average pH was fluctuated within the range of 7.4 to 9.0 in different treatments which implies that the pH in all the pond water was more or less alkaline throughout the experimental period and the level is comparable with the observation of (Boyd and Green, 2002 and Islam *et al.*, 2008).

DO should be considered as a key factor if success in shrimp culture is to be achieved and therefore DO levels of >4.0 mg/l for shrimp culture has been recommended by (Zhang *et al.*, 2006). Morning DO remained within the suitable limit and DO was recorded maximum 6.8 mg/l and the minimum was 3.3 mg/l in 5 and 3.1 mg/l in 7 stocking density of long culture in this case additional oxygen was supplied with aerators at late night hour usually after 91 days of culture whenever necessary. The transparency of the present study is between 25 and 45 cm which is similar to the agreement of (Ramakrishna, 2000; Soundarapandian and Gunalan, 2008). The recommended alkalinity is to be >80 mg/l for successful culture of *P. monodon* (Hansell, 1993), however in the present experiment the alkalinity level in different treatments varied between 106 and 160 mg/l Table 3 that is conducive for shrimp culture.

Table 3. Water quality parameters in different treatments of short and long culture.

Variables	1st short cycle crop (60 days)			2nd short cycle crop (60 days)			Long cycle crop (120 days)		
	Stocking density (Nos/m^2)			Stocking density (Nos/m^2)			Stocking density (Nos/m^2)		
	3	**5**	**7**	**3**	**5**	**7**	**3**	**5**	**7**
Tempe-rature (^{o}C)	29.5-32.0	30.5-31.5	29.0-31.0	30.0-31.5	29.7-32	30.5-32	29.0-32.0	30.5-31.5	29.5-33
Depth (cm)	106-124	95-120	95-125	116-122	104-127	106-125	96-118	94-115	114-126
Transpa-rency (cm)	27-38	30-45	28-40	25-45	28-44	22-37	32-47	28-42	25-36
Salinity (ppt)	11-17	11-17	11-17	6.5-10	6.5-10	6.5-10	7-17	7-17	7-17
pH	8.0-8.9	7.5-8.4	7.9-9.0	7.9-8.9	7.8-9.0	7.4-8.4	8.0-8.9	7.5-8.5	7.9-9.0
Morning DO (mg/l)	4.5-6.8	3.4-6.4	3.3-5.5	3.5-6.5	3.5-6.2	3.3-5.8	4.5-6.0	3.4-5.5	3.1-4.6
Alkalinity (mg/l)	122-140	134-158	128-155	115-135	106-136	128-160	126-140	134-160	130-155

3.2. Growth and production performance of shrimp

For the convenience of comparative analysis and to draw out the result more cognizable, production of two short cultures has been assembled to fulfill the culture period of long culture (120 days). The specific growth rates (SGR) of shrimp in every week for all the ponds are depicted in Figures 1, 2 and 3. From the presented figure it can be surmise that in the first 3-4 week of grow-out period the SGR was higher in both short and long culture pattern and then reduce successively and evenly as long as the ending of culture period. The initial SGR was significantly higher in 2nd short culture than 1st short and long cycle culture. However, the highest deviation in SGR was observed in different treatments of 1st short cycle culture. This variation is due to over fluctuation in moulting of shrimp in different treatment that may be the result of variation in water quality parameters and other ecological conditions of ponds.

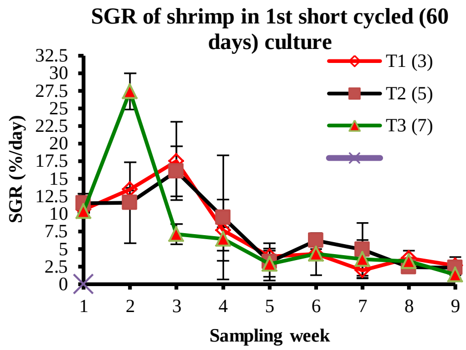

Figure1. SGR of shrimp in 1st short cycle.

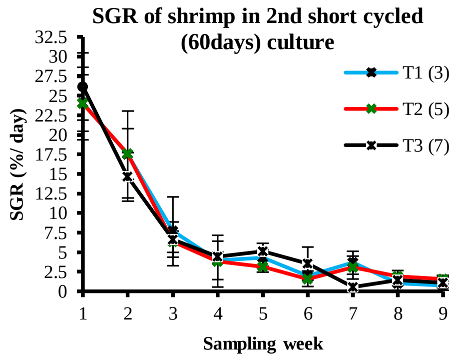

Figure 2. SGR of shrimp in 2nd short cycle.

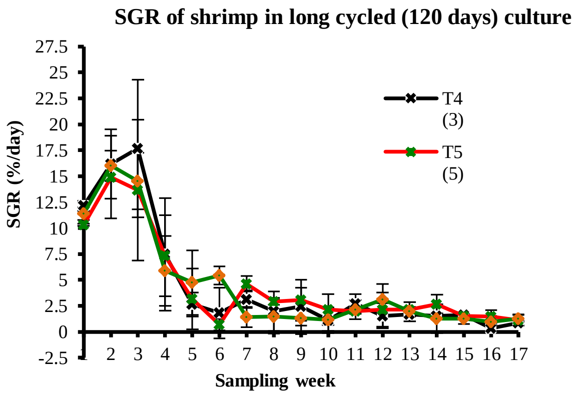

Figure 3. SGR of shrimp in long cycle (120 days) crop.

The production, survival rate and food conversion ratio (FCR) are shown in Table 4. Production of shrimp ranged between 990 kg/ha to 1998 kg/ha for short cycled double cropping pattern and1012 kg/ha to 2032 kg/ha for single cropping system. The highest production was obtained from T_6 of long culture (2032.26±31.0 Kg/ha) where the stocking density was 7 Nos/m^2 whereas the lowest was (990.17±2.52 Kg/ha) in T_1 of short culture where the stocking density was 3 Nos/m^2 (Figure 4). But the production between T_1 and T_4; T_3 and T_6 did not differ significantly (P>0.05) although the average production showed significant difference (P<0.05%) among the treatments of short and long culture patterns Table 4. However the production indices showed that the production was much more higher than the research report of (Islam and Alam, 2008), where production of shrimp culture for 120 days with stocking density 5 pcs/m^2, 7 pcs/m^2, 9 pcs/m^2 were 759.14 kg/ha, 670.77 kg/ha and 701.24 kg/ha respectively and the experiment of (Apud *et al.*, 1984) where production of shrimp was only 340 kg/ha with stocking density 4 to 5 pcs/m^2 for 125 days with supplemental feed and improved water exchange system. Similarly the production rate at 5 Nos/m^2 and 7 Nos/m^2 density is closely similar to the production of 1380 kg/ha in modified extensive system by (Laureatte *et al.*, 2012) and (2431.3±35.2 kg/ha) at 8 Nos/m^2 reported by (Hossain *et al.*, 2013).

An outstanding survival rate were found in different treatment which was ranged from 86.39 to 90.96% but did not show significant difference (P>0.05%) among the treatments of short and long culture cycle and the result is closely consistent with the survival rate reported by (Garriques and Arevalo, 1995 and Hossain *et al.*, 2013) , in probiotic treated ponds. Lowest FCR value was observed in T_3 (short culture) and the value was 1.13±0.00 and highest was found in T_6 (1.57±0.01) of long culture with stocking density of 7 Nos/m^2. However, there was

significant (*P*<0.05%) difference among the FCR value between different treatment of short and long culture as shown in Table 4. The FCR value of the present study is closely correspond with the FCR value reported for South East Asian countries shrimp farms (Corre, 1993) and survey result of (Ramaswamy *et al*., 2013) where they reported FCR value for different shrimp farming in India from 1.2 to 1.4. From the production and FCR data it can be clearly surmise that there was minimal significant difference among production of short and long culture with same stocking density although their FCR value differ significantly among different treatment.
The overall production and growth performance in both short and long culture cycle of crop diversification technology was satisfactory. These production rate implies that, production (Kg/ha) has been increased manifolds than the traditional culture practice. In the long cycle culture pattern it is obvious to supply additional oxygen for successful completion of grow-out period that is impossible to maintain by marginal and medium farmer. Similarly, for marginal and small farmer short culture (double crop) pattern will be more feasible because they could utilize their 1st crop return in their second short cycle crop production as their investment capacity is limited.

Table 4. Production performance of *Penaeus monodon* in different treatments of short and long culture.

Parameters	Short culture (60+60=120 days)			Long culture (120 days)		
Treatments	T_1	T_2	T_3	T_4	T_5	T_6
Stocking density(No/m^2)	3	5	7	3	5	7
Stocking size	0.005±0.0	0.005±0.0	0.005±0.0	0.005±0.0	0.005±0.0	0.005±0.0
Production	990.17±2.52^a	1485.23±7.15^b	1998.19±12.0^d	1012.31±4.34^a	1526.76±20.0^c	2032.26±31.0^d
Survival	89.2±0.61^a	89.59±2.4^a	89.41±1.20^a	87.76±0.82^a	90.96±1.26^a	89.80±1.02^a
FCR	1.16±0.01^b	1.17±0.01^b	1.13±0.00^a	1.51±0.01^c	1.52±0.01^c	1.57±0.01^d

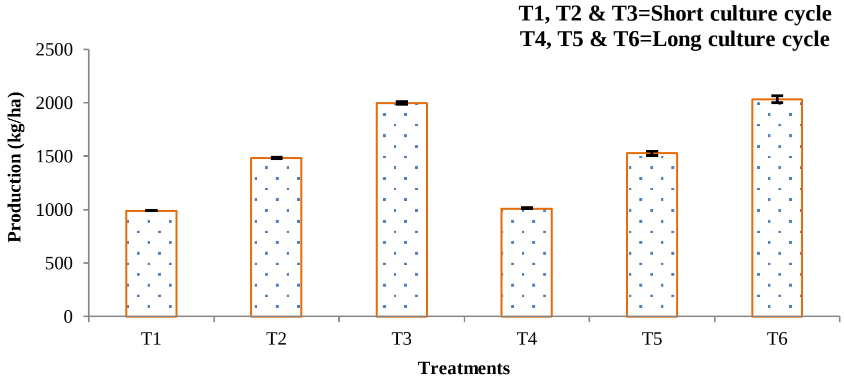

Figure 4. Production of shrimp in different treatments of short and long culture pattern.

3.3. Economics and return status of shrimp

The economic analysis of shrimp production under different stocking density covering short and long culture period has been presented in Table 5. Total amount of feed used were significantly (*P*<0.05) varied among the treatments as the culture period was different among T_1, T_2, T_3 as short culture (60 days) and T_4, T_5, T_6 as long culture (120 days). The highest amount of feed was used in T_6 (3190±7.0 kg).The expenditure of feed was also significantly (*P*<0.05) different among the treatments. The observed feed cost was highest in T_6 (414700±910 tk) and lowest was in T_1 (149257±1040 tk). For the successful completion of long culture (120 days) pattern supplementary oxygen were supplied with electric paddle wheels which appeared extra cost for all the treatments of long culture system.
On the other hand, the costs of PL were double for each treatment of short culture because of two times stocking. The highest total cost was observed in T_6 (598627±910tk) and lowest was observed in T_1 (345557±1040tk). However, the total cost was not significantly (*P*>0.05) different between T_1 and T_4 but was significantly different compare to other treatments. Except T_1 (543935±3308tk) and T_4 (556599±2389tk) the selling price varied successively according to production variation with significant (*P*<0.05) different among all the treatments.

The calculated net benefit were significantly (P<0.05) higher in T_3 (526310±4521) and T_6 (518862±15954) with a stocking density of 7nos/$m^2$and there was also significant (P<0.05) different between net benefit of different treatment of short and long culture cycle (Table 5). In West Bengal of India with scientific shrimp farming net benefit were BDT 1, 06,775/ha for small and BDT 4, 63, 458/ha for medium farmer reported by (Bhattacharya, 2009) which is closely similar with the present study. However, the net benefit (BDT 1, 98,378-2, 23,366/ha) obtained from short and long termshrimp culture with 3 stocking density in the present study is much higher than that of (BDT 56, 493.99-84,209.60/ha) reported by (Islam *et al.*, 2008), at 3 stocking density and (BDT 50, 105/ha) at 2 stocking density (Shofiquzzoha *et al.*, 2009), with same culture period.

Beside these, net benefitat 7 Nos/$m^2$is closely consistent with the research result of (Hossain *et al.*, 2013) at stocking density 8 Nos/m^2. The benefit cost ratio (BCR) in ponds with higher stocking density was higher in both culture pattern and there was no significant (P>0.05) difference between BCR of different treatment of long culture cycle, otherwise it showed significantly (P>0.05) lower than short term culture pattern.

Table 5. Cost of production and economic returns of shrimp from 1ha ponds for short and long culture period.

Parameters	Short culture (60+60=120 days)			Long culture (120 days)		
Treatments	T_1	T_2	T_3	T_4	T_5	T_6
Stocking density(No/m^2)	3	5	7	3	5	7
Feed used (kg)	1148±8.0[a]	1738±6.55[b]	2278±4.04[c]	1528±8.0[d]	2320±9.01[e]	3190±7.0[f]
Feed cost(tk)	149257±1040[a]	225971±847[b]	296226±525[c]	198640±1040[d]	301686±1172[e]	414700±910[f]
Chemical cost(tk)	61300±0.0	61300±0.0	61300±0.0	34927±0.0	34927±0.0	34927±0.0
PL cost(tk)	60000±0.0	100000±0.0	140000±0.0	30000±0.0	50000±0.0	70000±0.0
Labour cost(tk)	75000±0.0	75000±0.0	75000±0.0	75000±0.0	75000±0.0	75000±0.0
Electricity cost (tk)	0	0	0	4000±0.0	4000±0.0	4000±0.0
Total cost(tk)	345557±1040[a]	462271±847[b]	572526±525[c]	333233±17897[a]	465613±1172[b]	598627±910[d]
Selling price(tk)	543935±3308[a]	821413±4350[b]	1098837±3998[d]	556599±2389[a]	839244±11018[c]	1117490±16864[e]
Net benefit(tk)	198378±2284[a]	359142±4003[c]	526310±4521[d]	223366±18207[b]	373631±9852[c]	518862±15954[d]
BCR	3.06±0.005[b]	3.50±.005[c]	3.7±.01[c]	1.67±.09[a]	1.80±.02[a]	1.86±.02[a]

However it is clear that BCR in short culture cycle is much higher than that of long culture (120 days) which indicates higher net benefit as well as positive feasibility of short culture system. Except stocking density of 7/m^2 at short cycle culture net benefit were significantly (P>0.05%) higher in long cycle crop than that of aggregate of two short cycle crops. Considering the infrastructural facilities (electricity) in farm level and resource capability (investment) of farmers, this culture technology would be appropriate to boost up the production and income particularly for marginal to medium farmers.

4. Conclusions

Finally it can be concluded that production rate (kg/ha) under diversified cropping system is significantly higher than the recorded national average production rate. If the extension department (DoF) could successfully disseminate this diversified shrimp culture technology in field level particularly among marginal to medium shrimp farmers, the total national shrimp production would successfully increase and the country's economy will be boost up by earning foreign currency from the sustainable and growing shrimp production.

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Conflict of interest

None to declare.

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