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Participatory freshwater pearl culture for production of designer pearl with involvement of women at Takipara village of West Bengal, India

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Abstract
One on-farm trial on freshwater pearl culture was carried out at community level involving the women. Pearl culture was done in cages installed in semi-intensive carp culture pond. Implanted mussels were kept at a stocking density of 15 (T_1), 20 (T_2) and 25 (T_3) number per square feet area of each cage respectively. Five replicates were maintained for each treatment. Survival rate of mussels was observed 74.5 to 76.4% and was recorded the highest in T_3. 4.71 to 5.09% excellent quality and 44.89 to 45.61% good quality designer pearls were harvested from the treatments. The result showed the model can be up-scaled to increase per unit production in aquaculture sectors in rural areas by integrating pearl culture with fish farming for improving livelihood through diversification in aquaculture and increasing employability of the marginal fish farmers, especially, enabling the scope to involve the women.

Keywords: Freshwater aquaculture, diversification, designer pearl, community livelihood, women inclusion

1. Introduction
Pearl is a biological gem and also called queen of jewels for its gorgeous luster and being the only one that can be cultured (Alagarswami and Dharmaraj, 1984; Jin and Li, 2017; Patel and Sharma, 2019; Zhu *et al.*, 2019) [1-4]. Pearl sac tissue of mussel has biomineralization property (Luyer *et al.*, 2019) [5] which helps in pearl formation. When a foreign particle enters into the body of a muscle and the mussel fails to eject it out, it starts making layers of shiny coating called nacre on the particle (Alagarswami and Dharmaraj, 1984; Pandey and Singh, 2015) [1, 6] forming pearl. The same phenomenon is simulated for pearl culture. In the 13th century, Chinese were able to produce freshwater designer pearl for the first time (Alagarswami and Dharmaraj, 1984) [1] and presently the popularity of designer pearl is increasing worldwide (Bhargava *et al.*, 2020) [7].

Pearl culture is considered to be one of the major aquaculture activities in the world considering its value and trade (Pradhan *et al.*, 2019) [8] and it is an emerging income generation avenue for the marginal fish farmers especially, for the women members of those families in India. According to FAO (2016) [9], China is the pioneer of pearl production with over 98% of global share among which freshwater pearl is about 99.5% (Zhu *et al.*, 2019) [4]. India has also added its name in the list of the major pearl producing countries in the recent years as well as it is one of the largest importers of pearl also (Zhu *et al.*, 2019; Bhargava *et al.*, 2020) [4, 7]. Considering this domestic market along with abundant availability of natural waterbodies enriched with freshwater mussel diversity and available proven indigenous technology, there is an immense scope for propagation of freshwater pearl culture in India (Janaki Ram, 1997; Pandey and Singh, 2015; Saurabh *et al.*, 2016; Bhargava *et al.*, 2020) [10, 6, 11, 7]. The indigenous technology developed by different workers in India (Janaki Ram, 1989; Janaki Ram and Tripathi, 1992; Janakiram, 2003; Saurabh *et al.*, 2016) [12, 13, 14, 11] suggests *Lamellidens marginalis* (pond mussel), *Lamellidens corrinus* (paddy field mussel) and *Parreysia corrugate* (riverine mussel) as suitable species for freshwater pearl production in India.

The technology for producing designer freshwater pearl is quite simple (Saurabh *et al.*, 2016) [11] as well as cost effective (Bhargava *et al.*, 2020) [7] and has a success rate of 60-72% (Fassler 1992; Norton *et al.* 1996; Janaki Ram, 1997; Miah *et al.*, 2000; Saurabh *et al.*, 2016; Bhargava *et al.*, 2020) [15, 16, 10, 17, 11, 7]. Freshwater pearl culture can be performed with limited resources to obtain ROI (Returns on Investment) upto 200% (Bhargava *et al.*, 2020) [7], thus, has a prospect as cottage industry (Saurabh *et al.*, 2016) [11] ensuring rural livelihood improvement. In an endeavour to do the same and focusing on especially, involving women, initiative was taken to implement the freshwater designer pearl culture technology involving fishers' community of Takipara village, Balagarh block, Hooghly, West Bengal, India with an aim to create an alternate income generation opportunity utilizing their available resources for enhancing livelihood security which might be affected due to the ban in river fishing as a part of Hilsa conservation strategy in this zone of Hooghly river after declaring it a Hilsa sanctuary.

2. Materials and Methods

Freshwater pearl culture was conducted in an experimental basis in the freshwater pond having one Hectare area at Takipara village in Balagarh Block, Hooghly District, West Bengal, India (Lat. 23^0 2′31″N and Long. 88^0 26′22″E) owned by Dumurdaha-Takipara Fishermen Cooperative Society (FCS) involving the women members of the society. The pond is primarily utilized for semi-intensive carp culture. Pearl culture activity was incorporated to increase per unit production bringing diversification in aquaculture.

2.1 Mussel collection and acclimatization

Lamellidens marginalis (83.1±0.69 mm, N = 30) was collected by the community members of Takipara village from the local inland water bodies, such as ponds, beels, creeks etc. and transported to Takipara village within two hours of collection keeping in open aluminium handi (each filled with 30 L water) at a stocking density of 2 mussel/L of water. Then the mussels were kept for one week in the pond of Takipara village in nylon hapas (6 ft x 4 ft x 4 ft) fixed in the pond for acclimatization and the dead mussels were segregated, and removed from the hapas on daily basis.

2.2 Preparation of designer nucleus

Self-polymerizing acrylic material used for repairing of acrylic dentures (DPI-RR Cold Cure, pink) and jewellery designer moulds (Fig. 1) made with brass were procured from the market. This pack of DPI-RR Cold Cure consists of two parts; solid and liquid. The gel was prepared by mixing the solid and liquid provided within the pack in 1:1 (1 gm solid and 1 ml liquid). The desired amount of solid and liquid were mixed well rapidly into a container and the semi-liquid mixture was then filled in the cavity of each jewellery designer mould using a spoon. That process had to be completed very quickly otherwise the semi-liquid material would be hardened immediately. Before filling the cavity of each mould, it was brushed with coconut oil in order to remove the designer nucleus easily. After 10 to 15 minutes when the material turned hard in the moulds it was separated from the moulds using scalpel and steel blade. The outer edges of the nuclei remained uneven while detached from the moulds and they were then evenly shaped manually using cutting pliers (Fig. 2) and sand paper. After shaping, the nuclei (Fig. 3) were boiled in water for at least 15 minutes to remove odours of the acrylic material and disinfect. After boiling, these were dried by spreading on papers and then stored for future use as designer nuclei for insertion into the mussels.

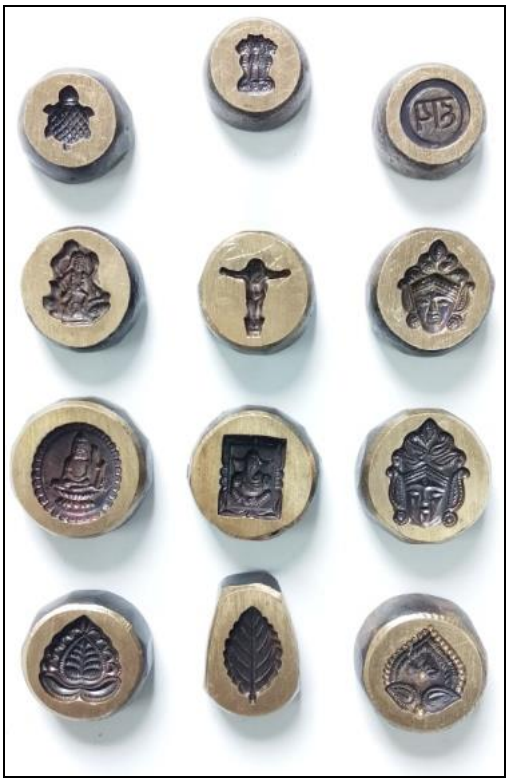

Fig 1: Designer brass moulds for preparation of designer nucleus

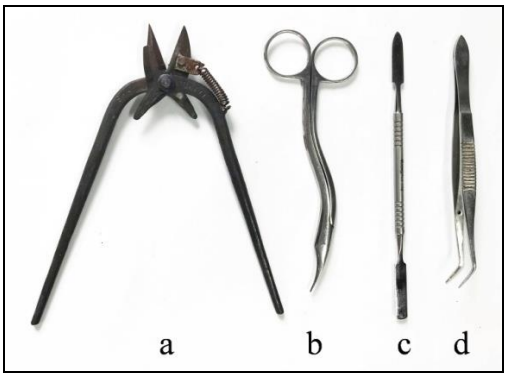

Fig 2: Major instruments required for designer pearl culture (a. cutting pliers, b. curved scissors used as shell opener, c. dental cement spatula, d. bent forceps)

Fig 3: Designer nuclei prepared for implantation into the mussels

2.3 Mussel surgery

During the month of January, 2019, the surgery was carried out. The acclimatized mussels were collected from the hapas and kept into plastic trays (15 x 12 inch) filled with pond water. Mussels were kept in ventral side up and dorsal side down position (Fig. 4) and placed in undisturbed and calm condition for half an hour to facilitate the opening of their valves naturally with ease. Here, the tip of the curved scissor was (length 150 mm) (Fig. 2) used as shell opener and as the mussel opened its valves only when the tip of the curved scissor was placed carefully in between the valves of the mussel and the inserted scissor's tip then restricted it to close again. Then a small piece of wood was placed at that position so that the valves were opened with a gap of about 6 to 10 mm (Fig. 5) keeping utmost care that increase in gap length between the valves could make no damage to the muscles and other soft tissues of the mussel. The surgery was done by putting the mussel on a piece of sponge kept on a small plastic tray (8 x 6 inch) (Fig. 5). Designer nucleus implantation was done during this experiment following mantle cavity insertion method (Janaki Ram, 1997; Saurabh *et al.*, 2016) [10, 11]. A small incision was made using a dental cement spatula (length 170 mm) (Fig. 2) near the ventral side of the mussel where the inner surface of the shell is attached with the mantle membrane. Then with the help of a bent forceps (length 150 mm) (Fig. 2) designer nucleus was inserted into the pocket and subsequently with the help of the dental cement spatula the nucleus was pushed slightly deep inside the mantle cavity to prevent ejection. After completion of the procedure, the wooden piece was removed and the mussel closed its valves normally. One nucleus in each shell was implanted during the experiment. Total 1050 number of mussels thus were implanted each with two numbers of designer nuclei.

Fig 4: Arranging position of mussels for opening valves before surgery

Fig 5: Implantation of designer nucleus into a mussel keeping it on a sponge sheet placed on a plastic tray and the valves of the mussel restricting to close using a small piece of wood

2.4 Post-surgical treatment

After completion of the surgical intervention, mussels were kept into circular plastic tubs (water holding capacity of 50 L, water filled with 30 L) in a stocking density @ 30 mussels/tub using pond water and with provision of aeration using aerator. Chloramphenicol was used at 5 mg/L following Mishra *et al.* (2008) [18] into the tub water to prevent secondary infections to the mussels after surgery. Half of water was exchanged from each tub using pond water on daily basis and Chloramphenicol was added accordingly as per the dose mentioned earlier. It was kept under this treatment for 5 days. Ejected nucleus and dead mussels were removed during the course and data were recorded.

2.5 Pearl culture in pond

Galvanized Iron cages each of 2 sq. ft. size (2-ft. L x 1-ft. W x 6-inch H, mesh size - 1cm) with lid were constructed by the FCS members having skill for that. Mussels implanted with designer nuclei were kept in the cages and then immersed in the pond (Fig. 6) for culture. Mussels were kept at three stocking densities of 15 numbers/sq. ft., 20 numbers/sq. ft. and 25 numbers/sq. ft. in each cage and were considered as T_1, T_2 and T_3, respectively. Five replicates (cages) were maintained for each treatment and considered as R1, R2, R3, R4 and R5. Two numbers of extra cages containing mussels with nuclei were also maintained for each treatment. The extra cages were kept for sampling purpose. Thus, 30 mussels with 60 designer nuclei, 40 mussels with 80 designer nuclei and 50 mussels with 100 designer nuclei were placed in each experimental cage of T_1, T_2 and T_3, respectively. The remaining implanted live mussels were kept in separate cages after keeping in experimental and extra cages. Mussels from the plastic tubs which ejected nucleus during the post-surgical acclimatization period were not placed in the experimental cages and those were kept in other cages. The cages were hanged with the help of nylon rope from the bamboo poles fixed within the earthen pond (Fig. 7). The clearance of the cage from the pond bottom was about 1 to 1.5 ft. No supplementary feed specifically for the mussels was applied into the culture system. In every fortnight the cages were checked by the community members under the guidance of the research team and the dead mussel, if found any, was removed as well as data were recorded. The cages along with the mussel shell surface were cleared using brush to prevent bio-fouling and smooth exchange of pond water within the cage in order to maintain the conducive ecology for the bivalves.

Fig 6: Cages with implanted mussels were being placed in the pond for culture

Fig 7: Cages with implanted mussels hanging from the fixed bamboo pole in the pond

2.6 Harvest

After completion of the pearl formation as observed during the sampling, the mussels from the experimental cages of the three treatments were harvested. The mussels were sacrificed to get the valves with pearls. Each shell was separated carefully to avoid any kind of damage and the body debris of the mussels were cleared from the shells. The shells were then immersed into detergent-water (1 g detergent powder/L of water) and washed carefully using tooth brush. Then those were treated in salt water (5 g common salt/L of water). After keeping for 30 minutes into the salt-water, the valves were air-dried by keeping on papers. After the drying was over, the valves with pearl were segregated grade-wise and kept as shell attached raw pearls without any further processing for selling it to the wholesale market.

2.7 Sampling and analytical methods

In every month, one sample from the extra cage of each treatment was sacrificed to observe the progress in pearl formation process. The water quality parameters were analysed in monthly basis during the total culture period. Water quality parameters including pH and dissolved oxygen (DO) were analysed using pH tester (model no. HI98107), Hanna instruments and portable Dissolved Oxygen meter (model no. HI9146), Hanna instruments, respectively. Transparency was measured by Secchi disk (Trivedy and Goel, 1984) [19], whereas the other parameters were analysed following the methods of APHA (2012) [20]. The survival and other parameters were calculated using the below mentioned formulae:

1. Survival (%) = (number of mussels harvested from the replicate/ number of mussels stocked in that replicate) × 100
2. Mortality (%) = (number of mussels died in the replicate/ number of mussels stocked in that replicate) × 100
3. Category/Grade of pearl produced (%) = (number of pearls harvested of that category in the replicate/ number of nucleus actually harvested in that replicate) × 100
4. Number of nucleus ejected = {(number of mussels stocked in the replicate – number of mussels died in that replicate) x 2} - actual number of nucleus harvested from that replicate
5. Nucleus ejection (%) = [(number of nucleus ejected in a replicate/ {(number of mussels stocked in the replicate – number of mussels died in that replicate) x 2}] × 100

2.8 Statistical analysis

Results are presented as mean±standard error and were analyzed using Microsoft excel. Following Zar (1999) [21], the statistical analysis was done using SPSS 10.0 for windows (SPSS Inc., Chicago, IL, USA). Multiple comparisons of post hoc test (LSD) in one-way ANOVA was used during the significant test (p<0.05 significance level). Pearson's correlation test was followed during the analysis of correlation coefficient between mussel survival rate (%), different qualities of pearl production rate (%) and ejection rate (%) in three types of stocking densities.

3. Results and Discussions

Out of 1050 mussels which were implanted with designer nuclei, nine died within two days after the surgical intervention. No further mortality was observed during these five days of post-surgical acclimatization period. Hence, the post-surgical acclimatization period mortality rate (0.86%) was found to be negligible in the present study. Six number of nuclei were ejected in six acclimatization tubs (one in each) on the next day after surgery and no more nucleus ejection observed during these five days. Nucleus ejection was also found negligible in this study supported that the implantation surgery performed by the community people under the guidance of the technical team, was accurate as the ejection of nucleus is very common if not properly implanted (Alagarswami and Dharmaraj, 1984) [1].

Following the sampling observation result, harvesting was done during the month of April, 2021. Hence, the total culture period for this experiment was found to be spanned for 28 months. The formation period of designer freshwater pearl in present study was much higher than that of the experiments conducted by the other researchers (Janaki Ram, 1997; Janakiram, 2003; Saurabh *et al.*, 2016; Bhargava *et al.*, 2020) [10, 14, 11, 7] who found it was 8 to 12 months only. As the product in present study is shell attached type (Janaki Ram, 1997) [10], the longer time was taken during pearl formation might be due to many other factors, such as bivalve species, age of the specimens, availability of suitable chemical constituents in the pond water etc. In present study, *L. marginalis* used as the pearl forming bivalve, is a thin shell species (Rao, 1989) [22] which generally utilizes more energy in tissue growth and reproduction than shell formation (McMahon and Bogan, 2001) [23], though the species is considered as a suitable freshwater pearl producing bivalve species in India as reported by different workers (Janaki Ram, 1989, Janaki Ram, 1997, Pradhan *et al.*, 2019) [12, 10, 8]. Age of the samples may also affect the biomineralization process (Dodd, 1966; Ky *et al.*, 2017; Piwoni-Piórewicz *et al.*, 2017) [24, 25, 26] as well as the variation in availability of certain chemical constituents in water plays an important role during shell formation (Chakraborty *et al.*, 2020) [27] and thus the shell attached pearl production.

The survival rate (Fig. 8) found highest in treatment 3 (T3) was 76.40±2.48% (N = 5), though it did not vary significantly (P<0.05) among the treatments. Irrespective of treatments, the highest mortality was found in the first month during the total culture period, *viz.*, 5.33±0.82%, 6.00±0.61% and 4.80±1.02% (N = 5) in T1, T2 and T3, respectively and did not vary significantly (p<0.05) among the treatments. The survival rate was found better in present experiment than that of the findings of the other workers (Fassler, 1992; Norton *et al.*, 1996; Janaki Ram, 1997; Miah *et al.*, 2000; Saurabh *et al.*, 2016; Bhargava *et al.*, 2020) [15, 16, 10, 17, 11, 7] who had reported that the survival rates were 60-72% and one of the possible causes for this better survival during this experiment as mantle cavity insertion method was applied (Pandey and Singh, 2015) [6]. The mortality rate observed in this study was less and the mortality pattern in T1, T2 and T3 are presented in Fig. 9. The higher mortality rate during the first month of pond culture might be occurred due to any human error during surgical intervention and any other subsequent infections.

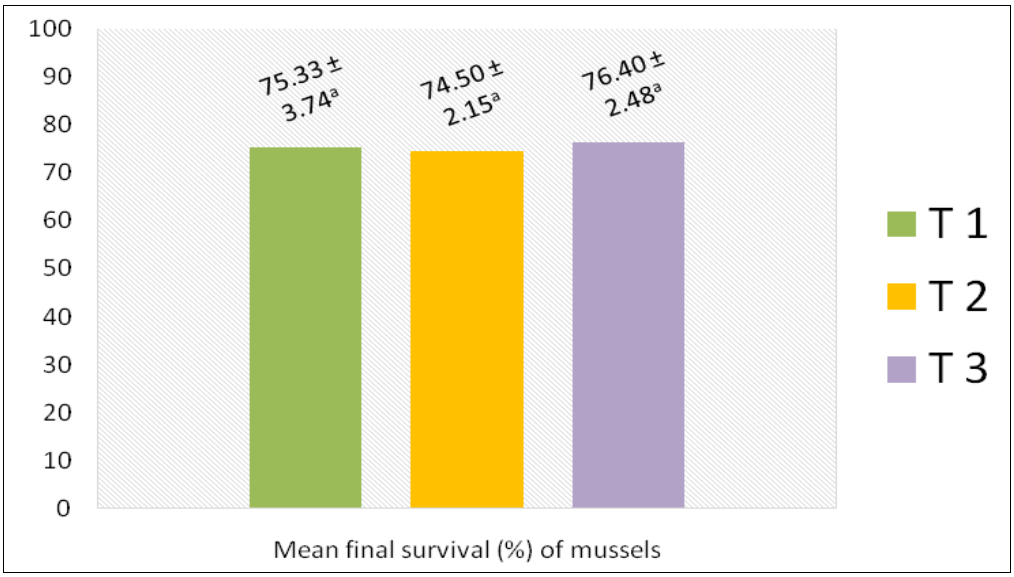

Fig 8: Survival rate (%) of mussels in T_1, T_2 and T_3 after 28 months of pearl culture in pond {Values with different superscripts differ significantly (p<0.05) and the values are expressed as mean (N = 5)±SE; T_1- 15 no. mussels/sq. ft. of cage; T_2- 20 no. mussels/sq. ft. of cage; T_3- 25 no. mussels/sq. ft. of cage}

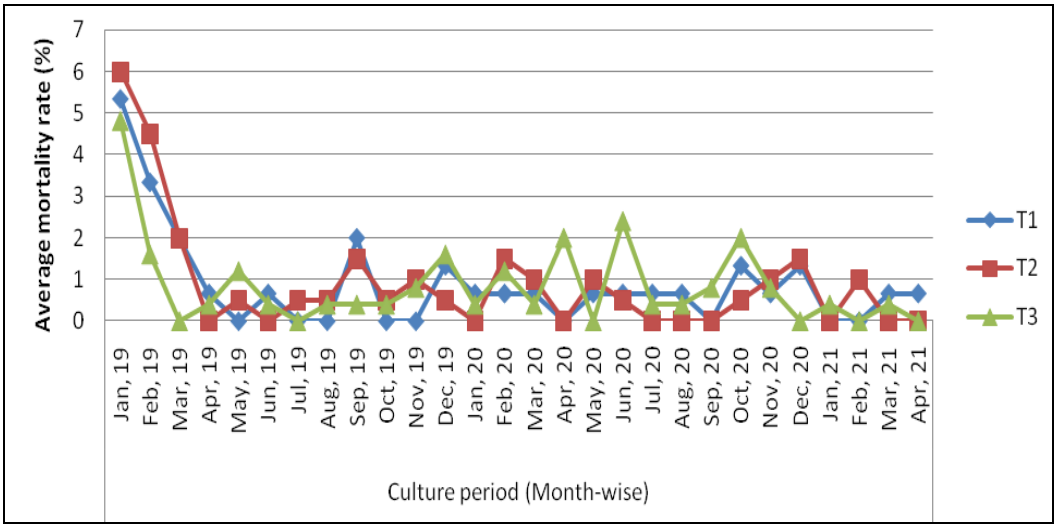

Fig 9: Mean mortality pattern of mussels in T_1, T_2 and T_3 during 28 months of pearl culture in pond (T_1- 15 no. mussels/sq. ft. of cage; T2- 20 no. mussels/sq. ft. of cage; T_3- 25 no. mussels/sq. ft. of cage)

After harvest and gradation, it was observed that out of total 600 mussels with 1200 numbers of nuclei available in all of the experimental cages in T_1, T_2 and T_3, 147 numbers of mussels died in total during the culture period and 294 numbers of nuclei went in vain. Sixty-five number of nuclei were ejected during the pond culture period. The remaining nuclei after formation of pearls (Fig. 10), were graded as excellent, good, moderate (may be used for handicraft making) and poor (cannot be used commercially) and there were 41 numbers of excellent, 381 numbers of good, 322 numbers of moderate (may be used for handicraft making) and 97 numbers of poor (cannot be commercially used) quality pearls harvested. The quality of pearl was measured as per the visual observation on formation quality *viz*., pearl surface, luster etc. (Ky, *et al*, 2017) [25] in absence of any other sophisticated instrument in the rural field condition. The harvests details are presented in Table 1. The rate (%) of different quality of pearls (as mentioned above) harvested from these 3 treatments are presented in Table 2. In the present experiment, a considerable amount of good quality pearl (44.89-45.61%) and excellent quality pearl (4.71-5.09%) were produced as some workers (Fassler, 1992; Norton *et al.*, 1996; Bhargava *et al.*, 2020) [15, 16, 7] had reported that only 20% saleable quality pearl and 5% top-quality pearl were generally found to be produced in pearl culture. In the present experiment, the ejection rate of nuclei were 8.34±2.42%, 8.10±1.01% and 5.80±1.01% (N = 5) in T_1, T_2 and T_3, respectively during the pond culture which was found to be less than 30-40% as reported by others (Fassler, 1992; Norton *et al.*, 1996; Bhargava *et al.*, 2020) [15, 16, 7]. The ejection rate (%) in the treatments also did not vary significantly (p<0.05).

Fig 10: Designer raw pearls harvested after 28 months of pearl culture in pond

Table 1: Harvest details of different qualities of pearl after 28 months culture in ponds in 3 treatments

Treatment	Replicate (cage)	Initial quantity of mussel	Initial quantity of nucleus	Mussels mortality	Nucleus cancelled due to mortality	Final possible availability of nucleus	Actual availability of nucleus after culture completion	Number of nucleus ejected during pond culture	Pearl quality			
									Excellent	Good	Moderate (may be used for handicraft making)	Poor (cannot be used)
T_1	R1	30	60	5	10	50	45	5	2	20	18	5
	R2	30	60	7	14	46	42	4	2	19	16	5
	R3	30	60	10	20	40	34	6	2	15	13	4
	R4	30	60	5	10	50	46	4	2	21	18	5
	R5	30	60	10	20	40	40	0	2	18	15	5
	Total (R1+R2+R3+R4+R5)	150	300	37	74	226	207	19	10	93	80	24
T_2	R1	40	80	11	22	58	54	4	3	25	20	6
	R2	40	80	8	16	64	61	3	3	28	23	7
	R3	40	80	10	20	60	54	6	3	25	20	6
	R4	40	80	13	26	54	49	5	2	22	19	6
	R5	40	80	9	18	62	56	6	3	25	21	7
	Total (R1+R2+R3+R4+R5)	200	400	51	102	298	274	24	14	125	103	32
T_3	R1	50	100	10	20	80	77	3	4	35	29	9
	R2	50	100	9	18	82	78	4	4	35	30	9
	R3	50	100	11	22	78	71	7	3	32	28	8
	R4	50	100	16	32	68	63	5	3	29	24	7
	R5	50	100	13	26	74	71	3	3	32	28	8
	Total (R1+R2+R3+R4+R5)	250	500	59	118	382	360	22	17	163	139	41
Total (T1+T2+T3)		600	1200	147	294	906	841	65	41	381	322	97

T_1- 15 no. mussels/sq. ft. of cage; T_2- 20 no. mussels/sq. ft. of cage; T_3- 25 no. mussels/sq. ft. of cage

Table 2: Harvest rate (%) of different qualities of pearl after 28 months culture in ponds in 3 treatments

Treatment	Quality-wise availability rate (%) of pearl			
	Excellent	Good	Moderate (may be used for handicraft making)	Poor (cannot be used)
T_1	4.89±0.27^a	44.89±0.27^a	38.59±0.44^a	11.63±0.29^a
T_2	5.09±0.28^a	45.61±0.35^a	37.61±0.32^a	11.69±0.29^a
T_3	4.71±0.21^a	45.30±0.21^a	38.62±0.36^a	11.37±0.10^a

Values with different superscripts in a column differ significantly (p<0.05) and the values are expressed as mean (N = 5)±SE. T_1- 15 no. mussels/sq. ft. of cage; T_2- 20 no. mussels/sq. ft. of cage; T3- 25 no. mussels/sq. ft. of cage

In the present experiment, it was observed that the tested stocking densities (T_1- 15 no./sq. ft., T_2- 20 no./sq. ft., T_3- 25 no./sq. ft.) did not have any effect on mussel survival, ejection rate of nucleus and on different qualities of pearl production as the 'r' (values p<0.05, 2-tailed), (Table 3) was found insignificant. Hence, no significant positive or negative correlation exists between mussel survival, ejection rate of nucleus and different qualities of pearl production in the tested three types of stocking densities in the present study. The water quality parameters remained in favorable range of aquaculture standards (Alabaster and Lloyd, 1982; Boyd and Tucker, 1998) [28, 29]. The water quality parameters recorded during 28 months culture period of pearl mussels are furnished in the Table 4.

Table 3: Correlation coefficient ('r' values) between mussel survival rate (%), different qualities of pearl production rate (%) and ejection rate (%) in three types of stocking densities (T_1- 15 no./sq. ft., T_2- 20 no./sq. ft., T_3- 25 no./sq. ft.) each with five replicates after 28 months culture in pond

Parameters	Correlation coefficient ('r' value)
Survival (%)	0.075
Excellent quality pearl production (%)	-0.137
Good quality pearl production (%)	0.262
Moderate (may be used for handicraft making) quality pearl production (%)	0.012
Poor (cannot be used) quality pearl production (%)	-0.205
Nucleus ejection (%)	-0.301

Correlation is significant for the values of 'r' with superscript * at P<0.05 (2-tailed), Correlation is not significant for the values of 'r' without superscript * at p<0.05 (2-tailed), N = 15

Table 4: Water quality parameters recorded in the pond during 28 months culture period of pearl mussels

Water quality parameter	Value
pH	7.58±0.04
DO (mg/L)	6.42±0.05
Total Alkalinity (mg/L)	144.9±1.80
Total Hardness (mg/L)	151.1±3.18
Transparency (cm)	27.2±0.30

The values are expressed as mean (N = 28)±SE

Being a freshwater mussel, *L. marginalis*, is a filter feeder and mainly feeds on plankton (Patil, 1974; Dan and Gu, 2002; Mandal *et al.*, 2007) [30, 31, 32], and during the present study specific food for mussels from outside was not applied into the culture system as the ponds in this geographical area are natural habitat of this bivalve species as well as this pond of Takipara village is utilized for semi-intensive carp culture, hence, naturally abundant with phytoplankton and zooplankton species. It was observed in this experimental period that this pond contained a good amount phytoplankton belonging to the class Chlorophyceae (Green algae) and Bacillariophyceae (Diatoms) which are very much preferred food items of *L. marginalis* (Mandal *et al.*, 2007) [32]. The transparency (Table 4) observed in this pond water was also found to be suitable for aquaculture as per the conclusion of other workers (Hossain *et al.*, 2008; Ahmad *et al.*, 2013; Khan *et al.*, 2018) [33, 34, 35].

Table 5 represents the details of cost involved and probable income (as per existing market rate) from the produced pearls of present trial. During the calculation of Benefit-Cost Ratio (BCR), only the cost and benefit related to the 3 treatments were considered. Labour cost for the operational purposes including mussel collection, was not considered during the calculation of BCR as the FCS members involved in this programme, and acted as laborer.

Table 5: Details of expenditure and probable income after 28 months of pearl culture in T_1, T_2 and T_3 (T_1- 15 no. mussels/sq. ft. of cage; T_2- 20 no. mussels/sq. ft. of cage; T_3- 25 no. mussels/sq. ft. of cage)

SL. No.	Particulars	Quantity required for each treatment	Rate (In INR)	Amount of total cost (in INR)		
				T_1	T_2	T_3
I	**Expenditure**					
A	Fixed Capital Cost					
1	Cage	5 pcs	300/pc	1,500.00	1,500.00	1,500.00
2	Designer brass moulds	50 pcs	100/pc	5,000.00	5,000.00	5,000.00
3	Plastic tubs	T_1 - 5 pcs T_2 - 7 pcs T_3 - 9 pcs	150/pc	750.00	1,050.00	1,350.00
4	Plastic trays (15 x 12 inch)	5 pcs	100/pc	500.00	500.00	500.00
5	Plastic trays (8 x 6 inch)	10 pcs	50/pc	500.00	500.00	500.00
6	Surgical and other instruments – cutting pliers, curved scissors as shell opener, dental cement spatula, bent forceps	Cutting pliers- 2 pcs, Curved scissors- 4 pcs, dental cement spatula-4 pcs, Bent forceps-4 pcs	2,000 (L.S.)/set	2,000.00	2,000.00	2,000.00
7	Aerator and accessories		2,000 (LS)	2,000.00	2,000.00	2,000.00
Total				12,250.00	12,550.00	12,850.00
B	Working Capital Cost					
1	Chemicals (DPI-RR cold cure pink etc.) antibiotics etc.	1 set	1,000 (LS)	1,000.00	1,000.00	1,000.00
Total				1,000.00	1,000.00	1,000.00
Total (A + B)				13,250.00	13,550.00	13,850.00
II	Income (from experimental cages)					
A	Shell attached raw pearl (excellent quality)	T_1 - 10 pcs T_2 - 14 pcs T_3 - 17 pcs	200/pc	2,000.00	2,800.00	3,400.00
B	Shell attached raw pearl (good quality)	T_1 - 93 pcs T_2 - 125 pcs T_3 - 163 pcs	Avg. 150/pc	13,950.00	18,750.00	24,450.00
C	Shell attached raw pearl (moderate quality: may be used for handicraft making)	T_1 - 80 pcs T_2 - 103 pcs T_3 - 139 pcs	70/pc	5,600.00	7,210.00	9,730.00
Total (A + B + C)				21,550.00	28,760.00	37,580.00
III	Benefit-Cost Ratio (BCR)					
A	First cycle = total income / total cost (fixed capital expenditure + working capital expenditure)			1.63	2.12	2.71
B	Second cycle and onwards = total income / working capital expenditure			21.55	28.76	37.58

4. Conclusions

The present experiment established that in alignment of the emerging trend in freshwater pearl culture in India, it can be up-scaled in potential area of West Bengal involving the marginal aquaculture farmers for bringing diversification in freshwater aquaculture resulting in increase in income and employability. Freshwater pearl culture can be incorporated along with pisciculture in ponds as an extra income generating avenue as pearl culture does not hamper the pisciculture and require much additional management interventions rather if cultured with fish in integrated mode, it may increase production per unit area thus, enabling additional income. The pearl culture also reserves the potential of gender inclusion as women can easily adopt this technique and thereby can create an avenue of employment for rural marginal women. Thus, transfer of this standardized aquaculture techniques and implementation of the same for mass scale production of pearl in area specific model may contribute to the increase in aquaculture production augmenting livelihood option of fish farming community.

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6. Conflicts of interest

There is no conflict of interest.

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