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# Enhancing profitability through improved seeding techniques in green mussel (*Perna viridis*) farming

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## Abstract

In mussel farming, the high investment costs on polyethylene ropes and operating costs due to transplanting mussel seeds can be reduced through the use of new seeding techniques. New methods were attempted by transplanting *Perna viridis* (L.) seed to 12 mm diameter polyethylene ropes on which biodegradable cotton net was wrapped and stitched together (control), 12 mm frilled polyethylene rope (Fuzzy™) with white fully degradable tubing socks (FuW) and grey semi-degradable synthetic tubing socks (FuG) and 5 cm broad flexible plastic strips (FPS) kept inside pre-stitched biodegradable cotton net. The treatments, which were replicated, were suspended from a fixed rack in a shallow tropical estuary (Ashtamudi Lake). The specific growth rate (SGR) in length and weight, fallout percentage and production in different treatments were compared. There was no significant difference in the SGR in length and weight, while the fallout percentage was significantly ($P<0.05$) lower and production significantly ($P<0.05$) higher in FPS and control treatments. Since the FPS and control treatments did not show any difference in terms of growth and production, the economic performance of these two methods were compared. The economic analysis indicated that the use of FPS together with pre-stitched biodegradable cotton net reduced the investment costs by 34% and increased the rate of return by 48% over that of the control.

## Introduction

The green mussel *Perna viridis* (L) is widely distributed along the east and west coasts of India. Annual production from wild ranges from 10,000 - 25,000 tonnes. The Spanish system for rope culture of this species was adapted to Indian conditions during the seventies using bamboo rafts as grow-out structures (Qasim *et al.*, 1977; Kuriakose and Appukuttan, 1980; Parulekar *et al.*, 1982). However, mussel farming was not taken up commercially due to problems in maintaining grow-out structures in the rough open sea conditions, threats to its security and low market demand.

In the nineties, the farming technology was modified to suit shallow brackishwater areas (Mohamed *et al.*, 1998; Velayudhan *et al.*, 2000, Asokan *et al.*, 2001). In these shallow estuarine areas where marine conditions prevail during the summer months (post and pre-monsoon i.e., November to May), the rack system is used to suspend ropes of cultured mussels. Here, the length of mussel ropes could be adjusted depending on the depth of the farming area (usually 1 to 3 m) thereby reducing the risk of loss of grow-out systems and mussel stocks. By the late nineties, this resulted in the development of commercial mussel farming especially in Kerala (Appukuttan *et al.*, 2000). At present there are more than 250 estuarine mussel farms in the State producing annually about 1,250 tonnes (in 2003).

Extraordinary growth performance, natural abundance, adaptability to new environments and fairly simple culture techniques make mussels of the genus *Perna* an ideal shellfish crop in many Asian countries (Vakily, 1989). Although the profitability of mussel farming operations in Indian waters can be high (Qasim *et al.*, 1977; Mohamed *et al.*, 1998; Asokan *et al.*, 2001), the returns obtained by farmers largely depended on the input costs. The rope method is also affected by losses (varying from 30 to 80%) due to fall-out or slipping of seeded mussels from ropes. Further, it has been reported (Velayudhan *et al.*, 2000, Asokan *et al.*, 2001) that the polyethylene rope used for seeding accounts for almost 40% of the investment cost. Presently the seeding method involves placing the mussel rope on biodegradable cotton netting, uniformly distributing the mussel seed and then manually stitching the netting around the rope and mussel seed. This process is labour intensive and seeding costs are estimated to range from 15-20% of the operating cost. The mussel tubing socks, widely used in Europe, have not been tried in India. The present study was taken up to explore the possibility of using alternate seeding material and methods to reduce costs due to seeding on polyethylene ropes. The quality of the alternate seeding material and method were assessed in terms of growth, production and percentage fall-out of mussels from the rope. Simultaneously, the dynamics of growth of the mussel *P. viridis* in shallow estuarine systems was also investigated.

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## Material and methods

Experiments were conducted in a portion of the Central Marine Fisheries Research Institute's demonstration rack farm (0.04 ha) in the estuary of Ashtamudi Lake (8°45′ – 9°28′ N and 76°28′ – 77°17′ E) in the southern district of Kollam in Kerala State. The lake has a permanent opening to the Arabian Sea and the farm is situated about 3 km from the mouth. The average depth at the farm is 1.5 m and the tidal amplitude (semi-diurnal) has a maximum height of 0.9 m. Typical marine conditions prevail from December to May. During the other months the estuary is strongly influenced by the monsoon rains, resulting in low salinities. Experiments were initiated in January 2000, when mussel seeds were available (Appukuttan *et al.*, 2001), and closed by

June 2000 (153 days of culture).

The experimental design involved 3 treatments and one control, each of which had three replicates. Mussel seeds picked from nearby intertidal and subtidal areas were cleaned of all debris and attachments and transplanted (seeded) on 1 m length treatment material and control ropes. The seeding rate was uniformly 1 kg.m$^{-1}$ (21.8 mm DVM; 974 numbers/kg). The process was completed within 3 hr of picking, so as to avoid stress and mortality to seeds. The first treatment material used was a 5 cm broad and 0.1 cm thick flexible plastic strip (FPS treatment), commonly used in camp cots and chairs (Fig.1A). Instead of using the conventional seeding method, the biodegradable cotton net were pre-stitched into tubes having a diameter of 6-7 cm and then the FPS was placed inside the tube after which the bottom end was knotted and the tube filled with seed mussels. The second treatment (Fig.1B) consisted of frilled 12 mm polyethylene rope with white fully degradable tubing socks commercially used in Canada and known as Fuzzy™ (FuW treatment). The third treatment (Fig.1C) was the same rope (Fuzzy™) with grey semi-degradable synthetic tubing socks (FuG treatment). The Fuzzy™ ropes were gifted by M/s Atkinson and Bower Ltd, Shelburne, Nova Scotia, Canada and are specially designed to improve mussel attachment and prevent slipping or fall-out of mussel seed.

The control was 12 mm polyethylene rope on which the mussel seed were spread and the cotton biodegradable net was wrapped and stitched together with nylon twine (Fig.1D). All treatment and control ropes were hung from the rack

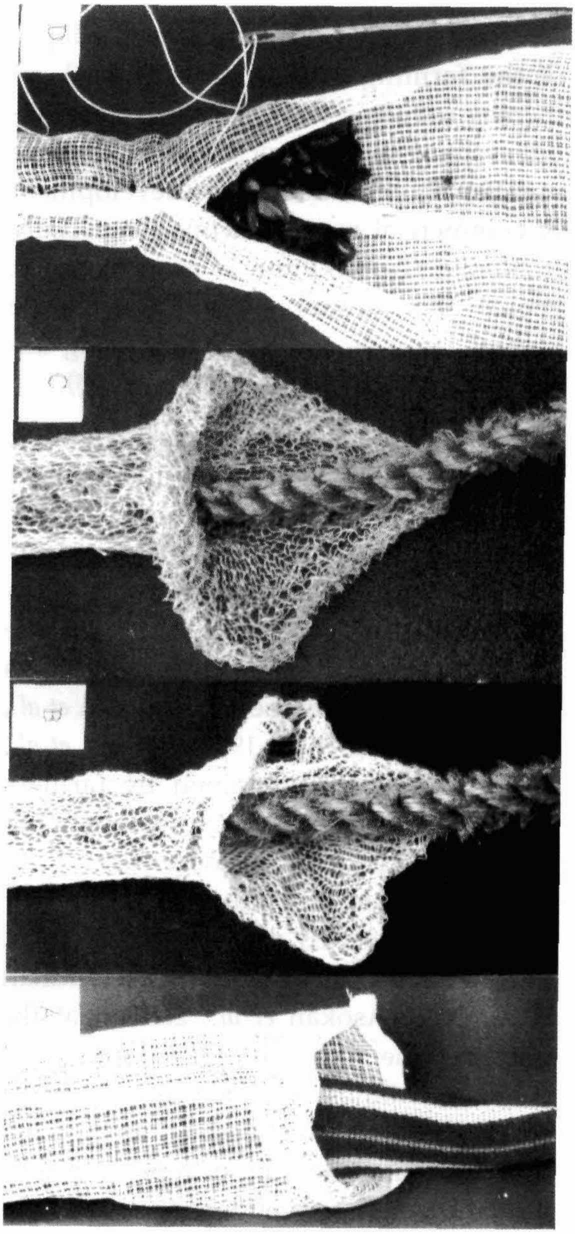

Fig. 1. *Experimental treatments used for transplanting (seeding) mussel seeds - EPS (A); FuW (B); FuW (C) and control (D).*

structure. Measurements of shell length (nearest 0.1 mm), total mussel weight (nearest 0.1 g) and meat weight percentage (weight of flesh/ total mussel weight X 100) were made for all treatments after 70, 105, 132 and 153 days of culture from sub-sample taken from each replicate. Fresh settlement of mussel seed observed in FPS treatment on 153$^{rd}$ day was excluded. All the control group of ropes was accidentally taken on the 132$^{nd}$ day along with other harvests, and therefore, data for control was available only up to 132$^{nd}$ day. Production (kg.m$^{-1}$ rope) and fall-out percentage (average number per metre rope) were calculated for 153$^{rd}$ day for all treatments, except the control where it was taken on 132$^{nd}$ day.

Mean length and weight and standard errors were calculated for all data. The specific growth rate (SGR) in length and weight was calculated using the following formula (Hopkins, 1992).

$$SGR = \frac{\ln L_1 - \ln L_0}{t}$$

where, $L_0$ is the mean initial length or weight and $L_1$ is the mean length or weight after time t. The SGR in length and weight, fall-out percentage and production in different treatments were compared using one-way ANOVA. In case of in-homogeneity, Duncan's multiple range analysis was performed using SPSS software (Version 8.0) for comparing treatment means.

Input and labour costs for setting up the farm and mussel seeding and farm maintenance were recorded and later used for working out the investment, fixed and operational costs. Economic analysis was carried out separately for two different combinations, viz. use of polyethylene rope (existing method) and use of FPS treatment (improved method). The economic efficiency of the methods was evaluated by comparing the rate of return (profit + interest / investment x 100) and the break-even price of the product. All calculations were made for a unit farm of 0.0025 ha area having the capacity to hold 100 seeded ropes of 1 m length for a period of 5 months.

## Results

Growth in length of the mussels showed a rapid increase from start to end of culture (Fig.2). The control group showed marginally better growth over the experimental treatments up to day 132. Among the experimental groups, the FPS treatment showed the maximum length after 153 days. The growth in length in mm. month$^{-1}$ varied over a very narrow range from 10.39 (FuW) to 10.94 (FPS). When the SGR in length was statistically compared (Table 1), the means were not significantly different (P>0.05). The high-

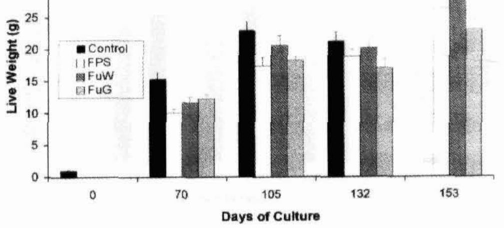


Fig. 2. *Growth in length in suspended culture of the mussel* P. viridis *under different treatments. Error bars indicate standard error of means.*

Table 1. *Comparison of mean SGR for length and weight, fallout percentage and production of mussels in different treatments using Duncan's multiple range test. Standard error values are given in brackets. Identical superscripts indicate no significant differences (P > 0.05) and non-identical superscripts indicate significant differences (P < 0.05).*

| Treatment | SGR (length) | SGR (weight) | Percent fallout | Production kg/m |
|---|---|---|---|---|
| FPS | 0.00774 [a] (0.00021) | 0.02075 [a] (0.0005) | 55.02 [a,b] (2.826) | 11.54 [a] (0.651) |
| FuW | 0.0074 [a] (0.00022) | 0.02113 [a] (0.006) | 83.42 [c] (2.887) | 4.67 [b] (0.563) |
| FuG | 0.00742 [a] (0.00024) | 0.02022 [a] (0.004) | 69.25 [b,c] (5.254) | 7.58 [c] (0.682) |
| Control | 0.00771 [a] (0.00024) | 0.02181 [a] (0.0005) | 39.38 [a] (9.974) | 12.60 [a] (0.586) |

est SGR was observed for control followed by FPS, FuG and FuW treatments and the differences were very narrow.

Increases in live weight during the culture period for different treatments are shown in Figure 3. The initial live weight of 1.02 g increased to a maximum of 28.9 g in FuW treatment. The growth in live weight in g.month$^{-1}$ varied from 4.62 (control) to 5.46 (FuW). Mean SGR for weight (Table 1) were not statistically significant (P>0.05) among treatments.

The general trend in the fresh meat percentage was that of decline (Fig.4) during the culture period. At day 70, the meat content percentage varied between 35 and 40. At day 105, the decline was gradual in control, FuW and FuG treatments and steep in FPS treatment. The FPS treatment again showed accumulation of meat at day 105 and then again showed a decrease. Final meat percentages varied between 28 and 39.

At a density of 1 kg.m$^{-1}$ rope, the number of mussel seed per meter was 974. By the close (153 days for treat-

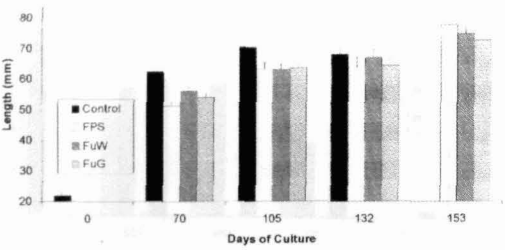


Fig. 3. *Growth in weight in suspended culture of the mussel* P. viridis *under different treatments. Error bars indicate standard error of means*

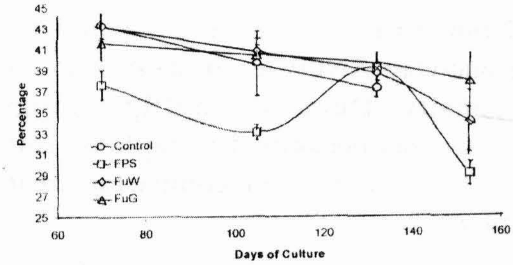


Fig. 4. *Fluctuations in percent meat content of the mussel* P. viridis *under different treatments. Error bars indicate standard error of means.*

Table 2. *Comparative economics of mussel farming by existing and improved methods. Area – 0.0025 ha; 100 seeded ropes of 1 m length, cultivation period - five months (All amounts in Indian Rupees).*

| | Criteria | Existing method | Improved method |
|---|---|---|---|
| A | Investment | | |
| | Bamboo poles – 15 nos | 1500 | 1500 |
| | Polyethylene rope for seeding | 1020 | - |
| | Others | 500 | 500 |
| | TOTAL | 3020 | 2000 |
| B | Annual fixed costs | | |
| | Interest (@ 15% per annum) | 453 | 300 |
| | Depreciation | | |
| | 1. Bamboo poles (50% per annum) | 750 | 750 |
| | 2. Polyethylene rope (50% per annum) | 510 | - |
| | 3. Others (50% per annum) | 250 | 250 |
| | TOTAL | 1963 | 1300 |
| C | Operating costs | | |
| | Annual lease | 500 | 500 |
| | Labour for rack construction | 750 | 750 |
| | Biodegradable cotton netting | 750 | 750 |
| | Mussel seed – 150 kg | 900 | 900 |
| | Flexible plastic strip | - | 200 |
| | Canoe hire charges | 750 | 750 |
| | Labour for seeding | 1200 | 700 |
| | Harvesting and marketing | 1500 | 1500 |
| | TOTAL | 6350 | 6050 |
| D | Total cost (B + C) | 8313 | 7350 |
| E | Production (kg) | 1260 | 1150 |
| F | Income @ Rs.8/kg | 10080 | 9200 |
| G | Net operating income (F-C) | 3730 | 3150 |
| H | Net profit (F-D) | 1767 | 1850 |
| I | Break-even price –Rs./kg (D/E) | 6.6 | 6.4 |
| J | Rate of return (%) | 73 | 108 |

ments and 132 days for control) of the experiment, the number of mussels per metre of rope had declined drastically due to fallout (ranging from 162 to 591 mussels/ metre). The percentage of mussels that fell off all treatments (percent fallout) is given in Table 1. Very high fallout was observed in FuW and FuG treatments, while it was moderate in FPS and control treatments. The mean fallout of control and FPS treatment was not significantly different (P>0.05), while those of control and FuW and FuG treatments were significantly different (P<0.05). Mean fallout of FuG and FPS treatment were also not significantly (P>0.05) different.

Production of mussels in the different treatments ranged from 4.67 in FuW to 12.6 $kg.m^{-1}$ rope in control (Table 1). The mean production obtained in FPS (11.5 $kg.m^{-1}$) and control treatments were not statistically significant (P>0.05). Comparatively low production was obtained in FuW and FuG treatments and these means were significantly (P<0.05) different from FPS and control treatments.

The comparative economics of mussel farming using the existing and improved methods are shown in Table 2. By using the improved method, the investment costs could be reduced by 34%. The improved method also showed considerable saving in the labour for seeding mussel ropes due to the use of pre-stitched mussel tubes thereby reducing the operating costs. The production per metre rope (Table 1), and therefore the income, was also marginally less when using the FPS. The net operating income was marginally higher in the existing method over the improved method. Net profit however, was enhanced by 5% in the improved method. The rate of return was comparatively higher by 48% for the improved method on account of the very low initial investment (Table 2). The improved method could also marginally decrease the break-even price giving additional leverage to farmers in marketing.

## Discussion

The specific growth rate is a common method used to compare growth in length and weight in aquaculture (Hopkins, 1992). The shell length growth rates of *P. viridis* obtained during the present experiments on different substrates (ropes and strip) compared well with those obtained by a number of previous workers (Kuriakose and Appukuttan, 1980; Parulekar *et al.*, 1982; Vakily, 1989; Rivonker *et al.*, 1993; Rajagopal *et al.*, 1998; Mohamed *et al.*, 1998; Velayudhan *et al.*, 2000) in tropical areas. Most authors (Rengarajan and Narasimham, 1980; Mohamed *et al.*, 1998) have also reported higher growth rate in the open sea conditions than in estuarine conditions, in spite of higher productivity reported in tropical estuaries (Qasim *et al.*, 1969). The presently observed mean monthly growth rate, in excess of 10 $mm.month^{-1}$ compared well with the 11-15 $mm.month^{-1}$ (Kuriakose and Appukuttan, 1980) obtained in the open sea conditions along the Indian coasts. The observed growth rates are higher than the 7-9 $mm.month^{-1}$ growth rates observed in other estuaries like Ennore (Rengarajan and Narasimham, 1980) along the east coast of India, Mulky (Mohamed *et al.*, 1998) and Chettuva (Velayudhan *et al.*, 2000) along the west coast of India.

Parulekar *et al.* (1982) reported that salinity was the dominant factor influencing growth in rope cultured green mussels in Goa. During the present experiments, as is usual in estuarine conditions, the salinity levels built up gradually to open sea conditions from January to June but showed a decrease in May due to heavy summer rains. Evidently, it is this less than ideal salinity and its fluctuations, that lower the growth rates of *P. viridis* under estuarine conditions. Notwithstanding this disadvantage in growth rates, estuaries are the preferred locations for mussel farming as evident by the 250 estuarine mussel farms existing in Kerala State. This is mainly because of the higher security and lower risks to mussel stocks in estuarine farm structures as compared to open sea farms.

Growth in live weight of *P. viridis* in estuarine conditions is also comparable with that observed in open sea conditions. Parulekar *et al.* (1982) reported an average monthly weight increment of 4.2 g in raft cultured green mussel at Goa, while Kuriakose and Appukuttan (1980) recorded a figure of 7.3 g in open sea conditions. The values observed presently (between 4.6 and 5.5 $g.month^{-1}$) are well within this range.

The meat weight as a percentage of total weight, which is a crude form of condition index (Vakily, 1989), showed a continuously declining trend in all treatments mainly because of the rapid and uncoupled increase in shell weight. The fluctuation in meat percentage, especially in FPS treatment, is indicative of loss of soft tissue weight due to spawning in April. A secondary spawning during February-April coinciding with increase in water temperature is common in the natural mussel beds along the west coast of India (unpublished). The fresh settlement of mussels on strips on 153$^{rd}$ day corroborates this inference. Rajagopal *et al.* (1998) also observed uncoupled growth rates between shell and soft tissues of *P. viridis* along the east coast of India resulting from spawning. Similar results are also reported from Beggars Island, southwest England (Salkeld, 1995) for *Mytilus edulis* populations. Mohamed *et al.* (1998) observed spawning of *P. viridis* kept in cages in Mulky Estuary during February-March. The present observations indicate that *P. viridis* is capable of spawning successfully in estuaries when marine conditions prevail.

Among the different treatments there were no significant differences in growth rate in length and weight indicating that the different ropes, strip and seeding methods used did not affect the growth rates. There were, however, significant differences in the fallout percentage and thence the production in the different treatments made. The fallout percentage was very high with the Canadian ropes and stocking tubes (FuW and FuG treatments). This was mainly because of the high elasticity of the stocking tubes, which resulted in non-uniform distribution of mussel seeds around the ropes. Further the large mesh size (1 cm) of the stocking tubes as compared to 0.5 cm mesh of the conventional cotton biodegradable net used in control and FPS treatment would have contributed to the slipping of the seed mussels during the initial stages. Losses due to fallout and predation are also reported to be high (61.5 to 72.5%) for *M. edulis* in tubing socks used in Scotland (Stirling and Okumus, 1994). In protected open sea conditions in Goa, Rivonker *et al.* (1993) reported nearly 90% fallout in green mussels grown on coir ropes for a year. However, the steep fallout stabilized after 6 months of culture. Similarly, Rajagopal *et al.* (1998) reported more than 80% fallout in *P. viridis* cultured on ropes for a year in Edaiyur Estuary along the east coast of India. Comparatively, the fallout percentages observed in the present study, especially in control and FPS treatment, are small. On harvest, these two treatments presented uniform distribution of mussels along the entire length of the rope and strip, suggesting that 400-600 mussels per meter is the maximum that can be accommodated in a metre of substrate in estuarine conditions.

The fallout percentage was also reflected in the production figures obtained in different treatments. The FuW and FuG treatments showed significantly low production per metre rope, while FPS and control treatments showed significantly higher production. Although very high production rates have been reported sporadically in literature (Rivonker *et al.*, 1993; Mohamed *et al.*, 1998; Rajagopal *et al.*, 1998), the commonly obtained production rate is about 10 $kg.m^{-1}$ rope (Kuriakose and Appukuttan, 1980; Quale and Newkirk, 1989). In commercial estuarine mussel farming in Kerala State (seeding procedure similar to control in present experiment), the average production is consistently above 10 $kg.m^{-1}$ rope (Appukuttan *et al.*, 2000). The present experiments indicated that the FPS and control treatments did not differ in terms of production and fallout percentage, while the FuW and FuG treatments showed significantly lower production and higher fallout.

The advantage in FPS treatment was the ease of filling up the pre-stitched cotton biodegradable tubes with mussel seed as compared to the manual drudgery of stitching. This directly resulted in halving of the labour cost involved in seeding. Results of the economic analysis indicate that by using the improved method, marked gains (by 48%) could be made in the rate of return. The polyethylene ropes used presently is 10 times more expensive than FPS and this study has shown that there is no significant difference in the production and fallout percentage due to its use. Although the FPS is a 'use and throw' type of material, its life could be extended by another year through careful use. The use of FPS as seeding substrate and pre-stitched cotton biodegradable net tubes can therefore be recommended for use to estuarine mussel farmers. Furthermore, use of pre-stitched tubes opens up the method for mechanisation of the seeding process.

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