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Concept of triangular raft design: Achieving higher yield in *Gracilaria edulis*

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ABSTRACT

The study describes utility of triangular raft design and the associated cluster arrangement in improving yield of commercially important agarophytes *Gracilaria edulis*. This simple modular design is cost effective, expandable, maneuverable, requires no specialized skills for assembly and could be easily practiced at individual cultivator level. Although, the average daily growth rate achieved in triangular raft ($5.01 \pm 0.64\%\ day^{-1}$) was quite comparable to conventional square rafts ($4.58 \pm 0.25\%\ day^{-1}$), the biomass yield per square meter in former was considerably higher (59.49%) than latter. Analysis of variance (ANOVA) showed that the raft shape significantly affected the biomass yield per square meter ($F = 16.58$; $p = 0.001$) but not DGR ($F = 3.847$; $p > 0.05$). The projected per hector earnings were 2.4 times higher in case of triangular raft than square rafts. The mean drag coefficient values were 1.72 and 2.51 for triangular and rectangular configurations respectively. Thus triangular configuration was subjected to less force on the front face (more stable) than the rectangular configuration. The method appears to be superior for cultivating the algae having fragile fronds such as species of *Gracilaria* which are more susceptible to breakage in response to wave action. The scaled-up experiments are underway to ascertain its utility for year round farming.

1. Introduction

The seaweeds are increasingly being cultivated rather than harvested from wild. Consequently, the global seaweed production has increased from less than 4 million wet tons in 1980 to almost 20 million wet tons in 2010 (FAO, 2013). Farming of seaweed for industrial utilization is inevitable as wild stocks are fast dwindling. Apart from biological attributes success of cultivation is essentially linked to the technological improvement in farming methodologies aimed at augmenting yield. Despite several studies ascribing yield potential to an array of biological features such as stain selection and hybridization, seedling production, disease resistance, genetic improvement, etc. role of structural designs in seaweed mariculture has by no means been explicitly investigated. Several systems – either floating or bottom dwelling – have been routinely employed in commercial farming. The most common are fixed off-bottom, rafts, cages, hanging long line, pens and tube nets. The choice of technique is of paramount importance which primarily depends on the physical characteristics of cultivation site. The structures with vertical alignment faces foremost impediment in marine environment due to horizontal force exerted by propelling waves. Thus 'floating square raft' is being popularly practised for several economically important seaweeds (Hayashi et al., 2011).

The square structure also has geometrical symmetry in the form of regular quadrilateral with four equal sides and four equal right angles. The predominance of right angles in architecture has long been recognized due to their role in providing stability to the structures (Steadman, 2006). The square timber frame having corners braced diagonally with smaller fragments ensures equal distribution of wave force over the entire raft area during cultivation. Besides yielding higher biomass, the advantages of raft system include minimal entrapment of sediments, reduced

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infestation as well as ease in maintenance and harvesting (Krishnan and Narayanakumar, 2013). It is well evident that floating raft system works well in near shore waters, but seldom effective in open sea where currents are strong and destabilizing forces are dominant. The alternative structural designs suggested for deep sea areas (Hurtado and Agbayani, 2002) are generally cumbersome to practice at individual farmer level and require specialized skills for assembly. This technological bottleneck needs to be resolved through innovative designs, which are easy to practice. The equilateral triangle is most stable because each side supported the two opposite sides, preventing them from moving in relation to each other. The present investigation demonstrates the utility of triangular shaped rafts in improving yield per unit area in industrially important red alga *G. edulis*. We also tested the hypothesis that triangular raft design is better in terms of strength, offers specific cluster arrangement that is more stable and has easy maneuverability than chain of square rafts, which is adopted routinely. This design further ensures low production cost by considerably reducing towards infrastructure and labor investment culminating into higher profit.

2. Materials and methods

2.1. Field cultivation

Ten 2 m × 2 m rafts as well as 2 m triangular rafts were used in the study ($N = 10$). The cultivation of *Gracilaria edulis* has been attempted at Gulf of Mannar coast (09° 17.057′N; 079° 10.989′E) near Mandapam, Southern India during a season characterized by moderate wave action (November–December, 2014). The method

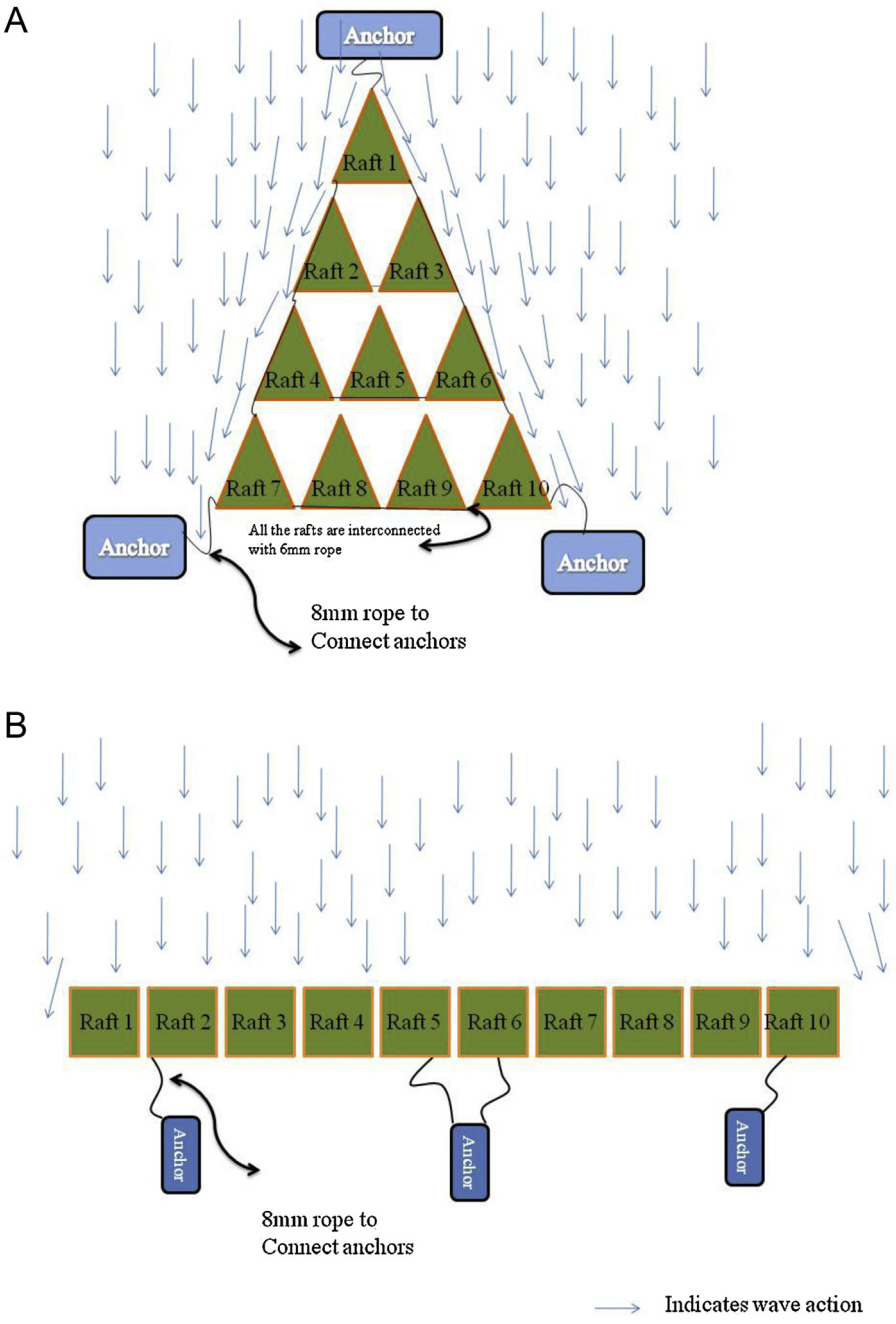

Fig. 1. (A) Triangular cluster arrangement of equilateral triangular rafts in a sea facing waves. (B) Rectangular cluster arrangement of square rafts in a sea facing waves.