Yield Improvement of *Gracilaria tentuistipitata* by Optimizing Different aspects in Coast of Cox's Bazar, Bangladesh

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Abstract

This research was designed to find out the effect of different factors such as influence of lunar cycle, harvesting interval, rope type and seeding gap on the production of *G. tenuistipitata* in coast of Cox's Bazar. Duration of these experiments were sixty days and all the parameters were recorded fortnightly. Monitoring of water quality parameters indicated that salinity, temperature, transparency, pH and DO were suitable for seaweed cultivation. In determining lunar cycle effect, results envisaged that fresh yield was 14.43% increased when seeding and harvesting time was selected considering the moon cycle. Regarding the selection of harvesting interval, it was found that T_3 (30 days interval) was the best to harvest the seaweed whereas T_4 (40 days interval) showed decreasing trend in production. Our study also found that semi floating single line showed better yield performance compared to semi floating double line system. In case of influence on seeding gap, it has been found that 20 cm gap between two seed showed the highest yields followed by 10 cm, 30 cm and 40 cm, respectively. Overall, it can be concluded that yield of *G. tenuistipitata* in coast of Cox's Bazar could be improved considering those factors.

Introduction

Seaweed is a colloquial term for the common name of mostly macroscopic and multicellular marine algae, which do not have root systems or flowers, leaves, stems, fruits and seeds and generally grow and live attached to rock or other hard substrata below the high-water mark or remain drifted in the oceans[1–4]. Seaweeds is considered as a high profile commercial marine biota for its variety of uses, like raw materials of bio-chemicals (agar, agarose, algin, and carrageenan), dyes, food, feed, enzymes and drugs [5]. Bangladesh is thought to be in the transitional zone for the flora and fauna of the Indian subcontinent and Southeast Asia and is part of the Indo-Burma biodiversity hotspot [6]. It has 710-km-long coastline and a 25,000-sq-km coastal area which is supported by a variety of land use practices. The seacoast of Bangladesh is considered as one of the unreached areas of the world in the field of phycology. This coastal area, with both sandy and muddy beaches, estuaries and mangrove swamps, provides substrates and habitats for the cultivation of various kinds of seaweeds, according to experts. *Gracilaria* species are notable for their economic importance as various products like agar, human food, animal feed, fertilizer, drugs, and biofuel are produced from it [7]. With a cosmopolitan distribution and high growth rates, this species is considered as good candidates for cultivation in various parts of the world [8].

Seaweed culture in Bangladesh is still in an initial stage. However, a few researchers are involved in seaweed cultivation in the south-eastern and south-western coasts of Bangladesh and the methods of cultivation of seaweeds using indigenous materials like bamboo and rope [6]. There are a few number of experiment conducted on culture of seaweed in Bangladesh where all of them either focused on the adaptation of culture technique based on environmental parameters or identifying potential sites for seaweed [9–11]. No experiment conducted regarding other possible factors which has influence on the yield performance of the seaweed culture in Bangladesh. Harrison and Hurd [12] reported that success in cultivating seaweed depends on both of the knowledge of ecophysiological characteristics of the species and on the important factors for seaweed growth that are responsible for better yields performance.

Hence, the aim of this study was to observe the effect of some crucial factors such as lunar cycle, harvesting interval, planting system and seeding distance on the production of seaweed *Gracilaria tenuistipitata* in Nuniarchara coast, Cox's Bazar.

Results

Water Quality Parameters

Seaweed culture needs suitable physico-chemical parameters. The mean (±SD) values of different water quality parameters during the experimental period are presented in Table 1.

Table 1. Mean values of water quality parameters during experimental period of 60 days

	Average water quality parameters				
Parameters	Salinity (ppt)	Temp. (°C)	Transparency (cm)	pH	DO (mg/L)
	32±0.3	22±0.1	74.5±1.4	8.0±0.1	7.2±0.1

Nutrient parameters

Nutrient parameters of water and soil in the seaweed beds of Nuniachara coast of Cox's Bazar are presented in the Table 2.

Table 2. Water and soil nutrients (mean±Sd) of seaweed bed in Nuniachara coast of Cox's Bazar

Water Parameters	**Unit**
Nitrate (NO_3) (mg/L)	0.632±0.2
Nitrite (NO_2) (mg/L)	0.443±0.11
Sulphate (S) (mg/L)	10,234.25±125.3
Calcium (Ca) (ppm)	437.30±7.1
Soil parameters	
Soil calcium (Ca) (ppm)	16,387.32±103.5

Effect of lunar cycle on the yields of *Gracilaria tenuistipitata*

In this experiment in T_0, seeds of seaweeds were transplanted three days after full moon and harvested three days before next full moon. On the other hand in T_1, seaweeds were harvested and transplanted in between two consecutive full moons. It is found that, full moon has impact on the yield performance of *Gracilaria tenuistipitata* (Table 3).

Table 3. Effect of lunar cycle on the yield performance of *Gracilaria tenuistipitata*

Treatments	Full moon during experiment	Fresh yield (t ha^{-1})	Dry yield (t ha^{-1})
T_0	12 December and 11 January	9.12 ± 0.66	1.55 ±0.19
T_1		7.97± 0.80	1.35±0.14
$\Delta T = T_0 - T_1$		1.15	0.20
% increase		14.43	14.81

The yields found higher in T_0 (where seeds were transplanted after full moon and harvested before the next full moon) than T_1 (in between two consecutive full moons).

Effect of harvesting interval on the yields of *Gracilaria tenuistipitata*

In this case, the impact of harvesting interval (10, 20, 30, 40 days) on the yield performance of Gracillaria *tenuistipitata* presented in figure 1.

It is found that the production increased in T_1, T_2 and in T_3 where the yields were highest in T_3 and the production decreased in T_4. These results indicate that 30 days of interval are the peak period to harvest the seaweed.

Effect of planting system on the yield

Two methods of planting system were followed to see the yield performance of *Gracilaria* species. It is found that the yield performance is better in semi floating single line (T_1) than semi floating double line (T_2) (Table 4 and 5).

Table 4 A. Yield Performance of *Gracilaria tenuistipitata* in semi floating single line (T_1)

No. of row	Fresh weight (ton/ha)	Dry weight (ton/ha)
1	12.78	2.03
2	13.63	2.18
3	11.99	1.92
4	13.52	2.16
5	11.79	1.87
Mean±SD	12.74±0.85^A	2.03±0.14^A

Table 4B. Yield Performance of *Gracilaria tenuistipitata* species in semi floating double line (T_2)

No. of row	Fresh weight (ton/ha)	Dry weight (ton/ha)
1	7.49	1.29
2	6.92	1.15
3	7.91	1.19
4	6.75	1.09
5	7.31	1.24
Mean±SD	7.28 ± 0.46^{B}	1.19 ± 0.08^{B}

Table 5. Yield Performance of *Gracilaria tenuistipitata* species in semi floating double line

(T_2)

The fresh yield of in semi floating single line was 12.74±0.8 t ha^{-1} that was significantly higher than the yield in semi floating double line system (7.28±0.46 t ha^{-1}).

The 20 cm length of planting distance showed significantly higher amount of yields (2.30 t ha^{-1}) than the other three treatments. T_4 which denotes the planting distance 40 cm showed the lowest yield performance (1.5 t ha^{-1}).

Effect of seeding distance on the yields of *Gracilaria tenuistipitata*

The yield of *Gracilaria tenuistipitata* seedlings in each treatments during the cultivation periods (30 days) is graphed in figure 2. It shows that the planting distances influence the yields of *Gracilaria tenuistipitata* ($p<0.05$).

Discussion

Seaweeds are not only source of food, feed and medicine but also a source of bioactive compounds which has nutritional and biomedical applications [13]. In recent years, seaweed cultivation has been an issue of much importance all over the world. *Gracilaria tenuistipitata* is an important seaweed species which has tolerant to a wide range of environments and an economically important raw material for agar production [14]. Most of the researches on seaweed farming is limited to searching the suitable location, selection of farming method and suitability of seaweed seed [10, 11, 15]. The success of seaweed farming does not only depend on ecological suitability of the site, but also to a large extent on some factors that also have impact on the production performance of seaweed. In this study, we evaluated influences of some other factors like effect of lunar cycle, rope type, harvesting interval and seeding gap on the improvement of production performances.

In these experiments, the water quality parameters and nutrient parameters of soil and water can be said suitable for seaweed culture according to other research findings [16–18]. *Gracilaria* has a high tolerance of environmental parameters [19–21]. The optimum environment could improve nutrient absorption process so that it could improve the growth rate of seaweeds.[10, 22, 23]

Regarding the effect of lunar cycle, seeding and harvesting was carried considering lunar cycle as tidal effect showed strong influence on the productivity of seaweed farming. Results showed that full moon has clear influential effect on the yield of *Gracilaria tenuistipitata* since during the day of full moon and three days before and after the full moon, the wave pressure remains higher than usual. Mulford [24] reported that when the moon is full, this causes a stronger pull-on ocean as the Earth and Moon are aligned, which causes a more pronounced tide. In present study, reduced yield performance recorded when seaweeds were harvested and transplanted in between two consecutive full moons. On the other hand, better yield performance recorded when the seeds were transplanted three days after full moon and harvested three days before next full moon. This was happened because during full moon in the middle or late of cultivation cycle, highest high tide and waves occur. Stronger high tide reduced the yield by storming off the long crop rope of *Gracilaria tenuistipitata.* Yield may be increased by 10 to 15 percent if we seed the crop three days before the full moon and harvest it three days after the next full moon (24 days field duration), instead of seeding at first day of the month and harvesting at last day (30 days field duration). Thus, we can save 6 days which can be used to dry and processing the harvest and also to take preparations for the next seeding. It has been found that harvesting duration also another factor which may influence on the productivity of seaweed farming. Timely harvesting of any crops ensures good crop quality and high market value. Another experiment also carried out to search out the suitable harvesting interval for obtaining better yield. In our present study, it is found that harvesting seaweeds after 30 days of seeding showed maximum yield performance. Reduced yield performance found when seaweeds were harvested after 40 days of seeding. The reason behind this could be rotting of the bunch of ropes of seaweed after 30 days of period and loss of the yield of seaweed has been occurred. Although no research findings is available in the literature regarding this factor, our study revealed that 30 days of harvesting interval is the peak period to harvest. Harvesting needs to be carried out in such a way as to maintain *peak* productivity.

Rope type has significant impact on the yield performance of the *Gracilaria tenuistipitata.* In our study, it has been seen that semi floating single line rope method was found better over semi-floating double line rope method and the yield was significantly higher in semi floating single line rope method. The higher yield was found due to fact that seeds of double line floating system were more submerged than the single line floating system and it happened to decompose the seeds of seaweeds and reduced the yield. Additionally, penetration of sunlight was less due to double line floating system which ultimately hampers the photosynthesis. Most of the researchers mainly focused on methodological approaches and main cultivation methods and discusses different problems arising during the application of these methods [25, 26] but no experiment found to be conducted regarding the planting method on the yield performance of *Gracilaria tenuistipitata.*

Seeding gap is a crucial factor for seaweed production. Neish [27] reported that the suitable planting distance will provide wider water circulation which take nutrients leading to enhance diffusion process in upgrading the metabolic and growth rate. In our present study, 20 cm length of seeding gap resulted significantly higher amount of yields. In this study, the 20cm-seeding gap is assumed to be suitable for receiving the intensity of sunlight in all thalli parts of *Gracilaria*, while in the other planting distance (10,30 & 40 cm) might be too narrow or too wide that indicates thalli's surface cover each other and also covered by filamentous epiphyte algae that impede sunlight absorption. These findings are in line with a report of Reddy *et al.* [28] and Aslin *et al.* [29] who found similar result in their experiment.

Taking all those factors into account, these studies revealed that *Gracilaria tenuistipitata* species could be cultured in our coast particularly in Nuniachara coast of Cox's Bazar. However, for getting maximum production, some effects such as lunar cycle, rope type, harvesting intervals of the seaweed and seeding gap need to be considered as our studies finds that there are influential impact of this factors on the yield performance of *Gracilaria* species. So, further research is needed to find out the effect of various factors on the yield performance of seaweed.

Methods

Study area: Study was conducted from December 2019 to January 2020 in Nuniachara of Cox's Bazar sadar. The cultivation of seaweeds in open sea is being carried out using one-step seed production method which requires healthy seaweeds. Taking the above considerations into account, experiment site has been primarily selected at Nuniachara coast of Cox's Bazar sadar.

Collection of seaweed seed: Wild *G. tenuistipitata* as seed was collected from Saint Martin's Island (92º28′40.12″E and 20º65′51.43″N) of Bay of Bengal of Bangladesh. Seed collection from seabed was permitted from the local government and authenticated the botanical identification of seaweed species as the voucher specimen has been previously deposited at BFRI herbarium.

Production of seeds: The farming/cultivation of seaweeds in open sea was carried out using one-step seed production method. Seeds for seaweed farming was produced by one-step (directly using cut pieces and tied with the ropes) and multi-step (inducing spore release by a particular seaweed in the green house and allowing spores to grow on ropes and nets) methods.

Seaweed culture method: The seeded ropes were arranged in single or double lines in the open sea. Each line was kept attached with two bamboo poles so that it could not be washed away. Plastic floats @ 5 pieces per 25 m long rope were used to keep the ropes moving up and downwards during tides. No fertilizer, insecticides and pesticides were used during seaweed cultivation.

Water parameters: Water temperature, salinity, transparency, pH and dissolved oxygen (DO) were checked every 15 days at the cultivation sites. Transparency was measured using Secci disc. A digital DO meter (HACH, USA) was used to determine the dissolved oxygen content of water. pH was measured using a digital pH meter (HACH, USA). Salinity was determined using refractometer.

Collection and analysis of soil: Soil samples from the sites were collected and after collection, samples were brought back to the laboratory within 6 h for analysis. In the laboratory, the samples were dried and powdered, sieved and kept in a desiccator until further analysis.

Optimization of different factors

Experiment 1: Effect of lunar cycle

This study was conducted to find out the effect of lunar cycle on the yield performance of *Gracilaria tenuistipitata.* In this experiment, T_0 indicates control where the seeds were transplanted three days after full moon and harvested three days before next full moon. On the other hand, T_1 indicates that seaweeds were harvested and transplanted in between two consecutive full moons where one highest high tide occurred.

Experiment 2: Effect of harvesting interval

In this experiment, different harvesting intervals (T_1 = 10 days, T_2 = 20 days, T_3 = 30 days, T_4 =40 days) were taken to determine the best harvesting time with *Gracilaria tenuistipitata* by harvesting after 10 days, 20 days, 30 days and 40 days of seeding, respectively for getting maximum production.

Experiment 3: Effect of rope type

Two types of rope (where T_1 denotes semi-floating single line method and T_2 denotes semi-floating double line method) were followed to evaluate the effect of this method on the yield performance of *Gracilaria tenuistipitata.*

Experiment 4:Effect of seeding gap

This experiment was carried out for determining the effect of seeding gap where T_1,T_2,T_3 and T_4 indicates 10 cm, 20 cm, 30 cm and 40 cm seeding gap, respectively on the yield performance of *Gracilaria tenuistipitata.*

Statistical analysis: Data were statistically analyzed by statistical package SPSS version 16.0 (SPSS Inc., Chicago, IL, USA). Before all analysis data were analyzed for normality by probability plots and for homogeneity of variances by Levene's test. One way ANOVA was used to determine the significance of each parameter among different treatments. If a main effect was significant, the ANOVA was followed by Tukey's test. Level of significance was made at 95% probability level.

Declarations

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Author's Contribution: Bokhtiar, Ali, Chowdhury, Ahmed designed and executed this research. Hassan and Ahmed reviewed this manuscript. Bhuiyan, Mashuk, and Rahman performed research design, data compilation, manuscript preparation and draft manuscript preparation. Rafiquzzaman supervised research activities.

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Figures

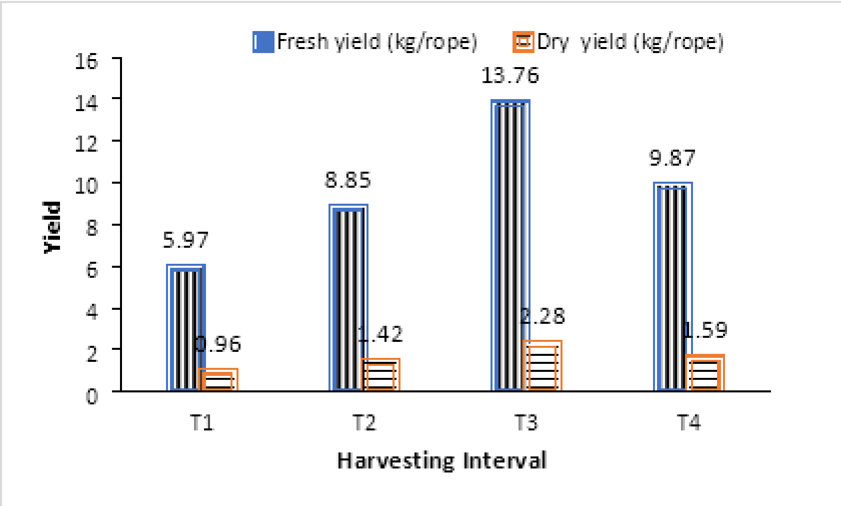

Figure 1

Effect of harvesting interval on the yields of Graciilllaria tenuistipitata

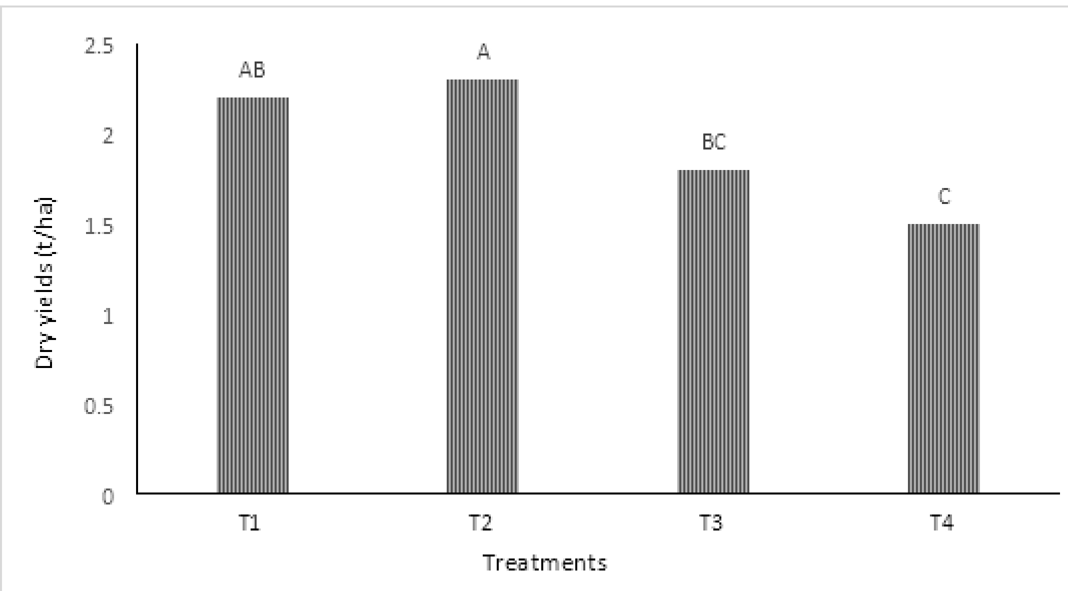

Figure 2

Dry yields in different seeding distance. Bars with different letters were significantly (p<0.05) different from each other