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Growth comparison of the seaweed *Kappaphycus alvarezii* in nine different coastal areas of Gujarat coast, India

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ABSTRACT

The present study is to known the water quality parameters and growth of seaweed Kappaphycus alvarezii in nine different coastal area of Gujarat coast. The growth measured in kilogram. Growth is a dynamic parameter and requires the increase in a certain quantity per unit time and maximum was recorded in summer, winter and monsoon season 22.4 kg, 16.7 kg and 11.9 kg in Okha mandal and the minimum growth was recorded 3.6 kg, 2.5 kg and 2.6 kg in Ghogha. Medium growth was recorded at Diu in all seasons (20.6 kg, 15.5 kg and 9.6 kg). Correlation coefficient of showed a significant positive correlation observed between total phosphate and nitrate ($P< 0.10 = 0.877$) and positive significant coefficient observed between seaweed growth and total phosphate($P< 0.05 = 0.750$). The results of water nutrients nitrate and total phosphorus was high in okha mandal area (summer 19.2 µg l^{-1} and 2.2µg l^{-1}, winter 17.4µg l^{-1} and 1.9µg l^{-1}, monsoon 15.4µg l^{-1} and 1.3µg l^{-1}) and lowest was recorded in Miyani village. This study indicates that out of nine stations Okha Mandal and Diu coastal area suitable for Kappaphycus alvarezii culture in summer, winter and monsoon seasons.

Key words: Seaweed Culture, *Kappaphycus alvarezii*, Water quality and Gujarat coastal area.

INTRODUCTION

Seaweeds are the natural sources of phycocolloids such as agar-agar, algin and carrageenan and they are rich in vitamins, minerals, protein, and essential amino acids and low in fat content.

Kappaphycus alvarezii is economically important red tropical seaweed highly demanded for its cell wall polysaccharides [1]. Commercial cultivation of *K. alvarezii,* originated in Philippines in 1960 [2], since then countries like Japan, Indonesia, Tanzania, Fiji, Kiribati, Hawaii and South Africa are cultivating this species on a large scale [3]. Farming techniques have undergone several innovations since it was first introduced. Today seaweed farming is a viable alternative source of income for small scale fishermen [4, 5]. In Tawi-Tawi (Mindanao, Philippines), seaweed farming is a major source of livelihood among seaweed farmers [6]. The seaweed cultivation has been adopted in Japan are for a number of seaweeds [7], in China for *Laminaria* spp. [8], in Taiwan for *Gracilaria* spp. [9,10] and in the Philippines for *Eucheuma* spp. [11,12,13]. Open ocean upwelling system has been used to establish cultivation of *Macrocystis* sp. in the Atlantic Ocean [14, 15]. The available data reveal that about 99% of *Eucheuma* spp. is commercially cultivated in Philippines, Indonesia, Malaysia and Tanzania. Experimental farming had been carried out in several countries including China, Venezuela, Japan, Fiji, USA (Hawai), Maldives, Cuba and India [7].

The Central Salt and Marine Chemicals Research Institute (CSMCRI), Bhavnagar, Gujarat, India procured a few fragments of the *Kappaphycus alvarezii* alga more than a decade ago, observing all protocols of introduction and quarantine. After acclimatization and laboratory culture, the alga was introduced in the sea under confined conditions that employed a novel bag technology, initially in the Gujarat coast of India and later in Mandapam, Tamil Nadu, southern India [16]. Although the alga introduced by the CSMCRI was of foreign origin, it was cited subsequently on the Andaman coast [17]. However, drifted *K. alvarezii* was reported from the Okha coast as early as 1970 by Krishnamurthy and Joshi [17]. In India, cultivation of this seaweed was initially started at Mandapam on the southeast coast of India [18],while some preliminary field cultivation experiments in tide pools were carried out at Okha during 1994-95 [19]. Attempts to cultivate this seaweed in experimental open sea stations at three Indian localities viz. Mithapur, Okha and Beyt Dwarka, were successful, and all the three sites were suitable for cultivation [20]. The first attempt at cultivation of a *K. striatum* was reported by Eswaran et al. [19]. A detailed report on the experimental cultivation of *K. alvarezii* was given by [18]. Recently, large scale *K. alvarezii* cultivation has begun at the Tamil Nadu coast [21]. Open sea farming of *Kappaphycus* sp. in India was performed by [22], successfully carried out pilot scale cultivation of *K. alvarezii* in Vizhinjam bay [23]. In India, the demand from the phycocolloid industry is great, but the present production from natural habitats is very low and not sufficient to cater the needs for local industry. This gap between the demand and supply can be bridged through mariculture practices and by cultivating the useful species on a commercial scale.

There are several reports on the experimental field cultivation of economically important seaweeds in different maritime states of India [24, 25]. Vegetative propagation method in different environments use various culture techniques [9, 26, 27]. Shoreline cultivation of *Kappaphycus* sp has been successfully established along the Gulf of Mannar and Palk Bay coast of Tamil Nadu, India [18] and similar cultivation is being organized along the Saurashtra coast in Gujarat. The aim of our present investigation was to determine the water quality parameters and growth of *K. alvarezii* in nine different coastal areas of the Gujarat coast, India.

MATERIALS AND METHODS

The experiment was conducted during three season at nine different coastal villages of the Gujarat region. (summer, winter and monsoon, Table 1). Young *K. alvarezii* germplasm was selected for the experiment. *K. alvarezii* (around 60 kg) was procured from Carrage Sea- Veg. Private Limited, Bhavnagar (Gujarat, India) and transported in an insulated van to the experimental site.

Plastic ropes of 3 mm thickness were used as a bit, where ten individual bunches of germplasm were tied by means of braider twine termed a loop. Loops of about 2 cm were secured by one end through the line plaits at intervals of about 15-20 cm. The other end of the loop was left loose. During planting the line was pushed through the loop, propagate inserted and the line snug pulled to secure the germplasm. There were five main ropes in a raft holding ten germplasm. The growth of the *K. alvarezii* was measured by weighing near the shore.

Table: 1 Culture stocking date details

Sr. No.	Winter			Summer		Monsoon	
	Location	**Raft place on dated**	**Harvested date**	**Raft place on dated**	**Harvested date**	**Raft place on dated**	**Harvested date**
1	Okha mandal	1/12/2008	2/3/2009	10/3/2009	11/6/2009	10/7/2009	11/9/2010
2	Arambhada	2/12/2008	3/3/2009	9/3/2009	10/6/2009	10/7/2009	11/9/2010
3	Miyani village	1/12/2008	2/3/2009	9/3/2009	10/6/2009	10/7/2009	11/9/2010
4	Navibunder village	1/12/2008	2/3/2009	9/3/2009	10/6/2009	10/7/2009	11/9/2010
5	Diu	1/12/2008	2/3/2009	10/3/2009	11/6/2009	10/7/2009	11/9/2010
6	Simar village	1/12/2008	2/3/2009	10/3/2009	11/6/2009	10/7/2009	11/9/2010
7	Rajapara	2/12/2008	3/3/2009	10/3/2009	11/6/2009	10/7/2009	11/9/2010
8	Jafrabad	2/12/2008	3/3/2009	10/3/2009	11/6/2009	10/7/2009	11/9/2010
9	Ghogha	2/12/2008	3/3/2009	10/3/2009	11/6/2009	10/7/2009	11/9/2010

Experimental Setup

Four good floating 12 feet bamboo poles for mainframes and four 6 feet bamboo poles for additional frames were selected for construction of a bamboo raft with the help of ropes. The interior part of the main frame was 3 x 3m^2 in size. Fish nets were tied under the raft to avoid the grazing. Around 12.5 kg of *K. alvarezii* germplasm was utilized at each selected site (2.5 kg per single floating raft). Approximately 2.5 kg of *K. alvarezii* were planted in each raft (1 x 1 m^2).Each raft had a total of five ropes of 3 mm thickness and the ropes consisted of five loops. The distance between the loops was 20- 22 cm. The 25 loops in the raft were inserted with 100 g *K. alvarezii* germplasm. A similar procedure was used for all the rafts at all nine stations. *K. alvarezii* growth was calculated after totally 60 days culture periods for each season (summer, winter and monsoon).Weakly monitoring the surface water samples for hydrography and nutrients studies, were collected by using a 5 l Niskin bottle. In situ temperature was recorded using thermometer (1–51_C range within ±0.1_C; Brannan, UK). Salinity was measured by argentimetry and nutrients were estimated following Grasshoff et al [31]

Statistical Analyses

Because of the similarity in topography and proximity of the nine study sites, the physico-chemical data recorded for these stations were used in the subsequent statistical analyses. Separate two-way ANOVA was performed to find out the significance in these parameters between seasons and stations. Correlation coefficient between four hydrographic parameters studied in the present study viz., water temperature, salinity, concentrations of nitrate, and total phosphates within each site including surface and bottom samples was analysed separately by the Pearson product-movement correlation coefficient [33]

RESULTS AND DISCUSSION

The growth of *K. alvarezii* on bamboo rafts is shown in Table 4 Values in the parenthesis indicate (mean ±SD).The weight of *K. alvarezii* in the summer, winter and monsoon seasons were 14.12 ± 5.58,10.85 ±4.02 and 6.32 ± 3.25 kg, respectively. The maximum was recorded in in Okha mandal (summer, winter and monsoon seasons 22.36, and 3 and 11.9 kg, respectively; NO_3-N was 12.64 ± 2.20 and total phosphate was 6.48 ± 6.29). In Diu was recorded next with 16.27 ± 27 and 2.05 ± 0.08 and the minimum growth was recorded 3.6, 2.5 and 2.6kg in Ghogha with 13.78 ± 1.41 and 1.27 ± 0.28 nutrients of NO_3-N and total phosphate was noticed . Medium growth was recorded at Diu in all seasons (20.64, 15.48 and 9.64kg) with 16.27±0.93 and 2.05±0.08. The results of water nutrients nitrate and total phosphorus was high in okha mandal area (summer 19.2 and 2.2kg, winter 17.39 and 1.86kg, monsoon 15.37 and 1.33kg) and lowest was recorded in Miyani village with nutrient NO_3-N 8.69 ± 0.40, total phosphate 1.28 ± 0.28. So this study shows that Okha mandal and Diu coastal areas are suitable for *K. alvarezii* culture in summer, winter and monsoon seasons. The most extensive growth is found in the summer season.

The seasonal difference was confirmed by the results of the ANOVA ($P<0.05$) represented in table 2. The results showed there was significant difference in between stations and seasons are significant at ($P<0.05$) level.

Correlation coefficient between nine hydrographic parameters studied in the present study viz., water temperature, salinity, concentrations of nitrate, and total phosphates within each site and samples was analysed separately by the Pearson product-movement correlation coefficient (Sokal and Rohlf, 1995). The Pearson correlation coefficient was calculated to find out the relationship between the hydrographic parameters in each site

Correlation coefficient (Table 3) of showed a significant positive correlation observed between total phosphate and nitrate ($P< 0.10 = 0.877$) and positive significant coefficient observed between seaweed growth and total phosphate ($P< 0.05 = 0.750$). Water temperature and salinity showed a insignificant correlation observed during the study period. This shows seaweed growth mainly depends with the total phosphate values during the study period.

Table.2 ANOVA Characteristic between Station and Seasons

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Location	414.0084	8	51.75105	16.8	1.995E-06	2.59
Between season	276.0306889	2	138.0153444	44.8	2.75517E-07	3.63

Table: 3 Correlation significant with Environment data with Seaweed growth

Parameter	W. Temp	Salinity	NO_3-N	Total P	Seaweed growth
W. Temp	1				
Salinity	-0.443	1			
NO3-N	0.406	-0.505	1		
Total P	0.267	-0.324	0.877*	1	
Seaweed growth	-0.200	-0.377	0.636	0.750**	1

**P< 0.01 significant, **P<0.05 significant*

Ta**ble: 4 Comparison of *K.alvarezii* growth**

Location		Mean of Raft in kg	Mean of Raft in kg	Mean of Raft in kg
		summer	**winter**	**monsoon**
Okha mandal	P1	22.36	16.73	11.9
Arambhada	P2	15.4	11.66	8.84
Miyani village	P3	12.5	10.74	6.68
Navibunder village	P4	12.9	10.4	5.48
Diu	P5	20.64	15.48	9.64
Simar village	P6	16.86	10.8	5.54
Rajapara	P7	11.7	9.72	2.94
Jafrabad	P8	11.1	9.64	3.26
Ghogha	P9	3.6	2.5	2.6

The water quality parameters salinity and temperature in all stations at summer, winter and monsoon not much variation was recorded. The nitrate and total phosphorus was high in okha mandal area (summer 19.2 and 2.2,winter 17.39 and 1.86, monsoon 15.37 and 1.33)and lowest was recorded in Miyani village (Table : 5,6,7).

Table 5 Water quality parameters in summer
Weakly collected surface water sample during the study period (Average summer values)

summer	W. Temp(°C)	Salinity(g/kg)	NO_3-N ($\mu g\ l^{-1}$)	Total P ($\mu g\ l^{-1}$)
Okha mandal	28	32	19.2	2.2
Arambhada	26	34.25	11.62	1.14
Miyani village	27.25	32.75	9.18	1
Navibunder village	27.5	34.25	12.41	1.62
Diu	27.56	33	17.51	1.93
Simar village	27.25	33.5	11.11	1.01
Rajapara	27.5	32.5	13.3	1.03
Jafrabad	27.5	33	12.57	1.03
Ghogha	28.25	33.75	12.18	0.95

Gujarat waters especially along Diu and okha mandal coasts provide conducive environments large scale cultivation of seaweeds [20]. The *K. alvarezii* showed maximum growth productivity (4.3 -6.1 g DW.$m^{-2}.d^{-1}$) similar to the results obtained in subtropical waters of Brazil [28]. According to the site fertility concept, seaweed growth rate is regulated by a complex interaction of irradiance, temperature, nutrients and water movements [29].

Table 6 Water quality parameters in winter
Weakly collected surface water sample during the study period (Average winter values)

Winter	W. Temp(^{o}C)	Salinity(g/kg)	NO_3-N (µg l^{-1})	Total P (µg l^{-1})
Okha mandal	23	31	17.39	1.86
Arambhada	23	34.25	9.69	0.99
Miyani village	20.5	32	8.2	1.58
Navibunder village	24	32.75	12.86	2.25
Diu	22	32	16	2.1
Simar village	22.75	33.5	12.35	1.47
Rajapara	23.25	33	14.35	1.05
Jafrabad	22.5	33.25	13.75	1.58
Ghogha	23.25	33.5	14.85	1.48

Table : 7 Water quality parameters in monsoon
Weakly collected surface water sample during the study period (Average monsoon values)

Monsoon	W. Temp(^{o}C)	Salinity(g/kg)	NO_3-N (µg l^{-1})	Total P (µg l^{-1})
Okha mandal	27.25	32.5	15.37	1.33
Arambhada	27.25	35	12.16	1.17
Miyani village	28.2	34.25	8.69	1.25
Navibunder village	27.5	34.25	11.76	1.62
Diu	27.2	32.25	15.29	2.11
Simar village	27.25	33.5	11.69	1.05
Rajapara	28.25	34	13.17	1.19
Jafrabad	28.5	34.25	14.27	1.61
Ghogha	28.75	34.5	14.32	1.38

Some of these factors may interact regulating the growth of target species and major decline of one factor (e.g. nutrients) could be compensated by another factor (water movement). Therefore, *Kappaphycus* sp. cultivation could be proposed as an alternative livelihood for fishermen, self-help groups and coastal poor people and same time it reduces the fishing pressure [30]. However, experimental testing of potentially useful farming areas, cultivation technologies and routines are needed before farms are expanded to large scale. So, the present study shows Okha mandal and Diu coastal areas are suitable for *K. alvarezii* in summer, winter and monsoon seasons.

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