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Preliminary assessment of potential farming sites for commercially important seaweed, *Kappaphycus alvarezii* in Lobo, Batangas, Philippines

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ABSTRACT

Kappaphycus alvarezii, locally known as guso, is a commercially important red seaweed because of its water-soluble κ-carrageenan. It also functions as an additive in commercial and pharmaceutical products. The continuous increase in demand in local and international markets has prompted the establishment of seaweed farming sites in the Philippines. However, the present scenario showed a decline in production due to occurrences of ice-ice disease and epiphytism. Most farming sites had also exceeded the carrying capacity for farming, including Calatagan, Batangas – the only seaweed farm in the province. Thus, this study aimed to identify potential farming sites outside Calatagan. Three sites in Lobo, Batangas were selected for assessment. On each selected site, a 3.57 m by 2.05 m floating raft with four monolines was deployed wherein seven *K. alvarezii* seedlings were tied in each monoline. The percent growth rate of the seedlings was monitored every week for one month alongside the physicochemical parameters i.e., water temperature, salinity, and depth. From the three sites assessed, Olo-olo showed the highest percent growth rate ranging from 2.11 to 3.63% d^{-1} followed by 1.17 to 2.12% d^{-1} in Sawang, and 0.72% d^{-1} in Lagadlarin. Moreover, values of about 30ºC, 32 ppt, and 1.8 m suggest that Olo-olo may be suitable for seaweed farming. With further studies, the site may be proven to be a potential farming site for *K. alvarezii*, which can serve as an alternative livelihood for the locals.

Keywords: carrageenophytes, percent growth rate, potential farming site, seaweed farming

1. Introduction

Kappaphycus alvarezii, locally known as guso, is a tough, fleshy, and firm marine red alga, that grows up to about 2 meters. It has coarse thalli with axes and branches. Furthermore, *K. alvarezii* grows small branches when situated in shallow areas, but its branches grow larger and entangle with each other forming fleshy mats when cultivated in deeper waters [1]. It is commonly found in coral reef areas with sandy or rocky substrate [2].

K. alvarezii is a commercially important seaweed because of its water-soluble κ-carrageenan [3, 4], which recently, was found to reduce the growth rate of mammary tumors in rats [5]. It is used in the production of edible films for the food and pharmaceutical industries [6]. Moreover, it contains antioxidants [7, 8] and is utilized in anticancer nutraceutical products [9]. *K. alvarezii* also serves as a balanced modulator between Firmicutes and Bacteroides for improved physiological processes in obese rats [10]. Additionally, the sap of *K. alvarezii* increases the tomato fruit yield [11]. *K. alvarezii* can also be used in the control of heavy metal pollution [12], fermentation, and biofertilizer and bioethanol production [13, 14].

The growing worldwide demand for its carrageenan resulted in increased prompts in the cultivation of *K. alvarezii* in seaweed-producing countries [4]. In the Philippines, *K. alvarezii* is the main seaweed species farmed among other varieties of seaweeds and constitutes 80% of the total Philippine production for export [15, 16]. *K. alvarezii* is mostly favored by farmers due to its fast-growing nature, ease to farm, and toleration to wide fluctuations of environmental factors [17]. Commercial seaweed production in the Philippines also proved to have an advantage for its low local production costs and high return of investment [18].

The municipality of Calatagan in the Province of Batangas in Luzon Island was one of the first sites where the pilot and experimental seaweed farming were established and became successful [19]. For more than three decades now, the seaweed farming in Calatagan has been flourishing and an income-generating business accounting to 122 permit holders to operate seaweed farming that covers about 2000 m^2. However, present seaweed production is declining in Calatagan with peak production during 2009-2011 [16].

The decline in production are due to consistent incidents of ice-ice disease, epiphytism, where access to sunlight or nutrients of seaweeds are blocked due to high abundance, and other farm-related problems i.e., sudden changes in physicochemical parameters and herbivore infestation, which could explain the low quality of its seed stocks. Most seaweed farms in the Philippines had also exceeded the carrying capacity for farming, including the farms in Calatagan, Batangas, the only seaweed farms in the province.

In the Province of Batangas, Lobo is considered to be one of the pristine coastal communities and has received an Outstanding Marine Protected Areas Award [20]. Based on preliminary site observations, Lobo could be a potential farming site. Thus, this study explored the possibility of Lobo as a potential new farming site for *K. alvarezii*.

2. Materials and methods

2.1. Study site

A preliminary assessment was conducted in selected sites in Lobo, Batangas (13.6750º N, 121.2401º E) (Figure 1).

The three sites were selected based on the preliminary observation that the sites met the required physicochemical parameters for seaweed farming i.e. water temperature, salinity,

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and depth [19]. In addition, the selected sites are accessible by both land and sea travel.

Figure 1. Map of Lobo, Batangas showing the three sites, namely, Lagadlarin, Olo-olo, and Sawang.

Lagadlarin (13.3736º N, 121.1241º E) has an approximate distance of 1,156.96 m to Olo-olo (13.3745º N, 121.1317º E) while Olo-olo has an approximate distance of 1,197.85 m to Sawang (13.3734º N, 121.1406º E).

Lagadlarin has an open water setting with a sandy substrate (Figure 2a). It is also near a mangrove forest, several residential houses, and fishing boats. Olo-olo has a lagoon-type setting with intertidal coral reef areas and sandy substrate (Figure 2b). There are few residential houses near the site. The setup is also near a big rock formation. Sawang also has an open water setting with intertidal coral reef areas and rocky substrate (Figure 2c). There are also a few residential houses near the site.

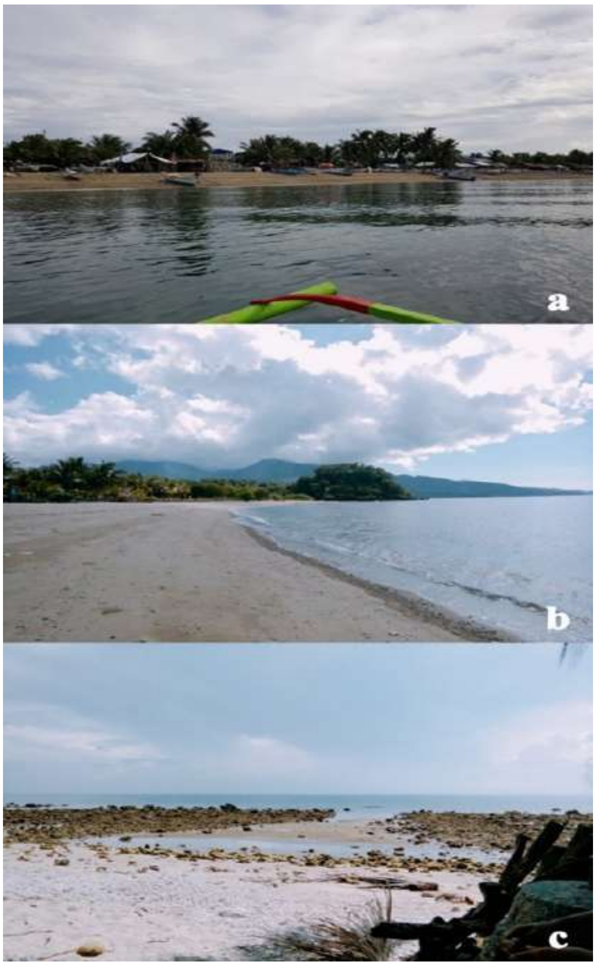

Figure 2. The photography of the study sites in (a) Lagadlarin, (b) Olo-olo, and (c) Sawang.

2.2. Seaweed material

The seedlings of the *K. alvarezii* (Figure 3) were collected from Edgar Limoico farming Corporation (ELfarCo) Seaweeds Farm in Calatagan, Batangas (13.8335º N, 120.6242º E) on September 23, 2018.

Figure 3. Photograph of the farmed *K. alvarezii* tied in a monoline collected from Calatagan, Batangas, and used for experimentation in the present study.

Eighty-four seedlings of *K. alvarezii* with an initial weight of 75g were transported to Lobo, Batangas, stored in a Styrofoam container with wet newspapers to prevent drying and to maintain the ambient temperature during the transports of approximately five hours. Upon arrival at the sites, the seedlings were placed inside a net bag and submerged in the open water for acclimation for about 24 hours before planting to heal wounds.

2.3. Experimental seaweed farm

Bamboo poles with a length of 3.57 m and a width of 2.05 m were used as frames and straw twines served as monolines. To avoid entanglement of monolines, another 2.05 m bamboo pole was placed in the middle of the frame and the straw twines were alternately tied to it. One raft consists of 4 monolines wherein 7 *K. alvarezii* seedlings were tied on each monoline in equal intervals for a total of 28 seedlings on each raft (Figure 4). One raft was deployed to each selected site.

Figure 4. Floating raft setup before deployment.

K. alvarezii seedlings were individually tagged (M*n*-S*n*; *n* is the number of monoline/seedling), weighed, and monitored every week for one month. Missing and loose seedlings were noted as well as signs of epiphytes, ice-ice disease, and grazing on each seedling if present. Moreover, other seaweeds found in the raft were removed.

The percent growth rate was computed using the formula based on [21] as shown in Eq. (1), where W_i is the initial weight in grams and W_f is the final weight in grams.

$$\%d^{-1} = \left(\frac{W_i}{W_f} \times \frac{1}{No.of\ days}\right) \times 100 \quad (1)$$

2.4. Measurement of physicochemical parameters

The physicochemical parameters of each site were measured every week for one month. The temperature (°C) was measured using an alcohol thermometer (TruLab®, Cubao, Quezon City, Philippines). Three readings were taken from the sites. The 1st reading was done before weighing the *K. alvarezii* seedlings. The 2nd reading was taken simultaneously as *K. alvarezii* seedlings were being weighed. The 3rd reading was done after *K. alvarezii* was weighed. The salinity (ppt) was measured using a handheld refractometer (YIERYI, Shen Zhen City, Guang Dong, Province, China) while the depth (m) was measured using a portable depth finder (NorCross Marine-Hawkeye DepthTrax™, 50 NE Dixie Hwy, Stuart, FL, USA).

2.5. Statistical analysis

The data was first subjected to a normality test using the Shapiro-Wilk test. If the data were not normally distributed, the data would have been transformed. One-way Analysis of Variance (ANOVA) was used to determine if the seedlings were able to reach the required growth rate in terms of mass in the selected barangays of Lobo, Batangas. All statistical analyses were done using the R software. Prior to ANOVA, the relationship of the growth rate on each site and the physicochemical parameters were also analyzed using regression analysis.

3. Results and discussion

3.1. The percent growth rate of *K. alvarezii*

Throughout the cultivation period, most of the *K. alvarezii* seedlings increased in weight. The highest recorded weight of *K. alvarezii* in Olo-olo and Sawang was 450 g and 400 g, respectively, during the 4th week of cultivation. In Lagadlarin, the highest recorded weight was only 90 g due to loss of raft setup from fishing activities around the area. Furthermore, some seedlings decreased in weight, which might be due to grazing and human interference i.e., fishing and tourism activities within the vicinity of the study site.

Olo-olo yielded the highest percent growth rate of *K. alvarezii* ranging from 2.11 to 3.63% d^{-1}, followed by Sawang with 1.17 to 2.12% d^{-1} (Figure 5). The percent growth rate of *K. alvarezii* in Lagadlarin was recorded at 0.72% d^{-1} during the first week, but the percent growth rate for the following weeks could no longer be determined due to loss of setup.

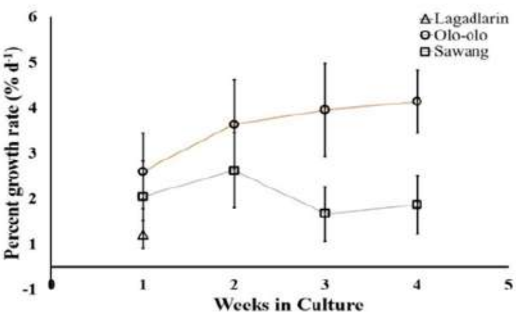

Figure 5. Comparison of the percent growth rate of *K. alvarezii* per week in the selected sites. Marker and error bars are the average of the weekly percent growth rate of the seedlings per site and their corresponding standard deviation.

Among the three sites in Lobo, Batangas, the percent growth rate of *K. alvarezii* in Olo-olo showed an increasing trend from 2.11 to 3.63% d^{-1}, which indicates the percent growth rate for a good farming site. According to [22], the optimum percent growth rate of *K. alvarezii* to be farmed in an area is about 2.3 to 4.2% d^{-1} in the Philippine setting. Moreover, percent growth rates ranging from 3 to 5% d^{-1} are deemed suitable for commercial farming [19, 23, 24]. However, the percent growth rate in Sawang exhibited an erratic trend, which might be due to the moderate to strong water movement caused by localized thunderstorms towards the end of the assessment [25].

3.2. Physicochemical parameters

During the entire assessment, the water temperature in Olo-olo remained constant at 30ºC while Sawang ranged from 30-31ºC. Furthermore, the salinity ranged from 31-34 ppt in Olo-olo and 31-33 ppt in Sawang. The depth also remained constant at 1.8 m and 1.2 m in Olo-olo and Sawang, respectively (Table 1). However, the changes in the physicochemical parameters in Lagadlarin could not be determined due to the loss of setup.

Table 1. Physicochemical parameters in Lagadlarin, Olo-olo, and Sawang.

Week	Physicochemical Parameters								
	Lagadlarin			Olo-olo			Sawang		
	ºC	ppt	m	ºC	ppt	m	ºC	ppt	m
1	30	30	30	30	32	1.8	30	31	1.2
2	nd	nd	nd	30	31	1.8	31	32	1.2
3	nd	nd	nd	30	34	1.8	30	32	1.2
4	nd	nd	nd	30	32	1.8	30	33	1.8
Mean ± STD	30	30	30	30 ±0	32.25 ±1.16	1.8 ±0	30.25 ±0.46	32± 0.76	1.35± 0.28

nd = no data

The values of temperature recorded from the sites were similar to the studies of [26], [27], [28], [29], [30] with ranges between 20 to 32˚C, 23 to 30˚C, and 30 to 32˚C, respectively. The increase or decrease in the percent growth rate of *K. alvarezii* is proportional to the changes in temperature [31, 32]. The variations in temperature also influence the physiology of *K. alvarezii*, such as photosynthesis, respiration, reproduction, and osmoregulation [33, 34], as well as carrageenan yield [35]. Furthermore, fluctuations in temperature initiate the occurrence of ice-ice disease and epiphytism as observed in the study of [36] and [37].

The obtained salinity was similar to the studies conducted by [38], [39], and [28] with ranges of 30 to 31 ppt, 31 to 34 ppt, and 32 to 35 ppt, respectively. The growth of *K. alvarezii* is adversely affected when salinity is lower than 30 ppt [19]. On the other hand, if the salinity exceeds to 40 to 50 ppt, it triggers hypersaline stress, which involves water deprivation, and hyposaline stress, which promotes the higher concentration of seawater inside *K. alvarezii* [40, 34]. Drastic changes in the salinity also result in epiphyte infection and ice -ice disease [37, 36].

The present study was conducted in shallow waters following the prescribed depth of 0.6 to 2 m during the lowest tide and highest tide of the day, respectively. However, most studies cultivated *K. alvarezii* in water with a depth of 4 to 17 m [41] and 5 to 25 m [42]. Cultivation of *K. alvarezii* in deeper water also yielded higher percent growth rates compared to the cultivation in shallow waters [43] because strong waves on the water surface make the underwater current still and enable the sunlight to penetrate through the water [29]. However, [44] observed that the percent growth rate of *K. alvarezii* decreased as the depth for cultivation increased. Thus, great differences in the tidal ranges may affect the distribution of nutrients and the growth of seaweeds [45].

3.3. Statistical analysis

The percent growth rate in each site did not differ significantly during the 1st week of culture (Table 2). On the 2nd week of culture, there was an increasing trend on both Olo-olo and Sawang, but did not differ significantly. However, on the 3rd week of culture, there was significant difference in the percent growth rate of *K. alvarezii* in Olo-olo and Sawang. The significant difference was evident until the last week of culture.

Table 2. The statistical analysis of the percent growth rate of *K. alvarezii* per week on each site in Lobo, Batangas.

Sites	Percent Growth Rate % d^{-1}			
	Week 1	Week 2	Week 3	Week 4
Lagadlarin	0.72±0.31 a	nd	nd	nd
Olo-olo	2.11±0.83 a	3.13±0.98 a	3.45±1.02 a	3.63±0.68 a
Sawang	1.55±0.77 a	2.12±0.83 a	1.17±0.60 b	1.36±0.64 b

nd = no data
ANOVA at p<0.05
Mean ± standard deviation with same letter is not significantly different

According to [23] the daily growth rate of *K. alvarezii* is 2.3 to 4.2% d^{-1}. Furthermore, based on the study of [24], growth rates above 3.5% d^{-1} are deemed suitable for commercial farming in the Philippine setting.

Based on the gathered data from the three sites, there is no significant relationship between the percent growth rate of *K. alvarezii* and the physicochemical parameters (Table 3).

Table 3. Relationship between the physicochemical parameters and percent growth rate of *K. alvarezii* in Lagadlarin, Olo-olo, and Sawang.

Sites	Physicochemical Parameters		
	Temperature (ºC)	Salinity (ppt)	Depth (m)
Lagadlarin	nd	nd	nd
Olo-olo	0.1329 (p=0.64)	0.0725 (p=0.73)	0.01132 (p=0.89)
Sawang	0.8566 (p=0.07)	0.03598 (p=0.81)	0.00016 (p=0.99)

nd = no data

Although there was no significant relationship between the measured physicochemical parameters and percent growth rate during the experiment, it could indicate that the physicochemical parameters were suitable for the growth of *K. alvarezii*, which conformed with the abovementioned ranges.

In the study of [48], it was stated that the growth rate and water temperature have a positive correlation. During the summer and autumn seasons, the growth rate of *K. alvarezii* was higher than those during the winter season with ranges of 4.29 to 5.12% d^{-1} and 0.32 to 0.54% d^{-1}, respectively.

3.4. Comparison of data between published studies and the present study

All values of physicochemical parameters gathered were within the ranges of published studies on seaweed farming (Table 4).

Table 4. Comparison of percent growth rate and physicochemical parameters of the potential farming site based on published studies and the present study.

Parameters	Published studies	Present study		
		L	O	S
Percent growth rate (%d^{-1})	3-5	0.72±0.31	2.11±0.83 to 3.63±0.68	1.17±0.60 to 2.12±0.83
Temperature (ºC)	25-30	30	30	30
Salinity (ppt)	28-35	33	32	31
Depth (m)	0.6-2	1.8	1.8	1.2

Several studies on *K. alvarezii* mentioned that the temperature and salinity of the site contribute to the increase or decrease in percent growth rate [46, 47, 30, 48, 49, 35, 50]. However, in the present study, there was minimal change in the physicochemical parameters. This implies that the percent growth rate of *K. alvarezii* might be independent of the changes in the physicochemical parameters in the sites in Lobo, Batangas. Moreover, the percent growth rate could be affected by grazing. There was also a drastic decrease in the growth when herbivorous fish were found within the cultivation area [38]. Herbivore grazing might pose a problem to *K. alvarezii* farms if not managed properly [23].

Overall, all gathered data on the percent growth rate of *K. alvarezii* and physicochemical parameters are within the prescribed ranges of a potential farming site [19, 23, 24].

4. Conclusions

The percent growth rate of *K. alvarezii* in Olo-olo is the highest among the three sites and is within the suitable range for commercial farming. Differences in the percent growth rates among the sites may be due to the topography of each site which might have influenced the water movement. The measured physicochemical parameters in the three sites also conformed with the published values and ranges. Furthermore, there is no significant relationship between the measured physicochemical parameters and percent growth rate. With this baseline information, establishing a seaweed farm in Olo-olo is deemed possible. This may also serve as an alternative livelihood for the residents.

Further study with replicates for each site and longer cultivation period in different seasons are recommended to fully determine the viability of the sites as seaweed farms. Cultivation of *K. alvarezii* in other coastal sites in Lobo, Batangas may be conducted. A study focusing on other physicochemical parameters such as water movement, dissolved oxygen (DO), light intensity, turbidity, and pH that affects *K. alvarezii* may also be conducted as well as the nutrient analysis of the water in the study sites. Also, testing of hybrid cultivars could be used for pilot testing in Lobo, Batangas. Lastly, a study using other cultivation methods such as fixed off-bottom, long lines, and cages may also be executed.

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