IOP Conference Series: Earth and Environmental Science

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To cite this article: Husniah *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **575** 012097

Growth performance of seaweed *Kappaphycus alvarezii* in different planting distance using long-line farming, Mandar Bay, West Sulawesi Indonesia

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Abstract. The present study aimed to determine different planting distances on the growth of Kappaphycus Alvarez using the longline method. The present study was conducted from September to October 2018 in Mandar Bay, West Sulawesi. Water quality measurement was performed in situ during the study period, including temperature, salinity, pH, turbidity, and water current and data collected on the specific and absolute growth of seaweed. Prior to study, buoys, rope, length measurement device, and anchor were prepared for seaweed cultivation. The long-line method was applied for seaweed cultivation, and the seed of Seaweed Kappaphycus alvarezii obtained from local seaweed farmers. A total of 10 stretches rope using different planting distance of 15 cm (P1), 30 cm (P2), 45 cm (P3), and 60 cm (P4). The cultivation was carried out for 5 weeks. The results showed that the highest specific growth rate and absolute growth were obtained from P3 in which the absolute growth reached 165 gr, and the specific growth rate was 0.14%, respectively. This finding suggested that different planting distance affects the growth of seaweed. In addition, the environmental parameters for seaweed cultivation were still considered in optimum condition for cultivation.

1. Introduction

Seaweed cultivation has globally contributed to aquaculture production of around 27 million tons in 2014 [1]. In the same year, Indonesia also contributed about 37% of seaweed production globally. Kappaphycus alvarezii has been known as one of the sought-after seaweed commodities in Indonesia [2]. It has encouraged local farmers to cultivate the seaweed due to nutritional values, as a source of carrageenan and for the manufacture of bioproducts of commercial interest such as cosmetics, pharmaceuticals, food, biofertilizers and biofilters [3].

The success of seaweed cultivation requires proper cultivation techniques [4]. One of cultivation technique used in farming seaweed is a long-line technique. This technique is closely related to planting distance. Moreover, it allows the seaweed to optimally utilize the sunlight for photosynthesis and nutrient from the water current.

The growth of seaweed is highly influenced by the planting distance, and the wider planting distance, the more nutrient can be absorbed, leading to maximum growth performance [5]. Lack of understanding of planting distance leads to poor carrageenan contain and growth performance. Because planting distance is a technical factor that significantly affects the growth rate in relation to nutrient absorptions, in addition, the optimal area utilization for seaweed farming should be considered by applying efficient and effective density of seaweed planting. Therefore, the aim of the present study

IOP Conf. Series: Earth and Environmental Science **575** (2020) 012097 doi:10.1088/1755-1315/575/1/012097

was to determine optimal planting distance for maximum growth performance and optimum land utilization of K. alvarezii using the long-line technique.

2. Method

2.1. Location
The present research was conducted from September to October 2018, where the study took place during the dry season in Mandar Bay, West Sulawesi Indonesia. On the west side of the coast, Mandar bay is directly bordered with Makassar Strait, Indonesia.

2.2. Prior to the study
Seaweed seed was taken from the fresh thallus of *Kappaphycus alvarezii*. Several measurement equipment and facility were prepared, including thermometers, pH meters, Secchi-disk, hand-refractometer, current meter, boats, buoys, cultivation ropes, and anchor.

2.3. Cultivation method
The long-line method was applied to the cultivation technique. A total of 10 stretches (cultivation rope) using different spacing, including P1 (15 cm), P2 (30 cm), P3 (45 cm), and P4 (60 cm).

2.4. Data collection
Data collection was conducted once a week for 5 weeks. The absolute and specific growth rate was calculated as follows:

2.4.1. Absolute growth rate. Data on AGR was collected from day 1 to the end of the study period, according to Effendi (2003) [6] and calculated using the equation below:

$$G = Wt - W0 \quad (1)$$

Where:
G: absolute growth (g);
Wt: initial weight (g);
W0: final weight (g).

2.4.2. Specific growth rate (SGR). The equation suggested by Dawes (1994) [7] to calculate the SGR were applied as follows:
Where:

$$\text{SGR} = \frac{lnW_t - lnW_0}{lnW_0 \; x \; t} x \; 100\% \quad (2)$$

SGR: specific growth rate (%);
Wt: initial weight (g)
W0: final weight (g)
t: study period (week)

2.4.3. Data analysis. Analysis of variance (ANOVA) was performed for significant differences between treatments (P<0.05) using SPSS 22 version. A significant difference between treatments was further tested using the Tukey test.

3. Results and discussions

3.1. Result

The highest absolute growth rate obtained from P3 treatment (165 g) and the lowest absolute growth rate obtained from P1 treatment (145 g) (Figure 1). Nonetheless, all the treatments tend to gain weight every week (Figure 2). The results showed a significant difference between the group of treatment ($P<0.05$). The Tukey test indicated that the P3 and P4 were having a similar effect on the growth performance of seaweed. However, the P1 and P2 were not the same as those two treatments. P1 and P2 tend to have a slower growth rate compared to P3 and P4.

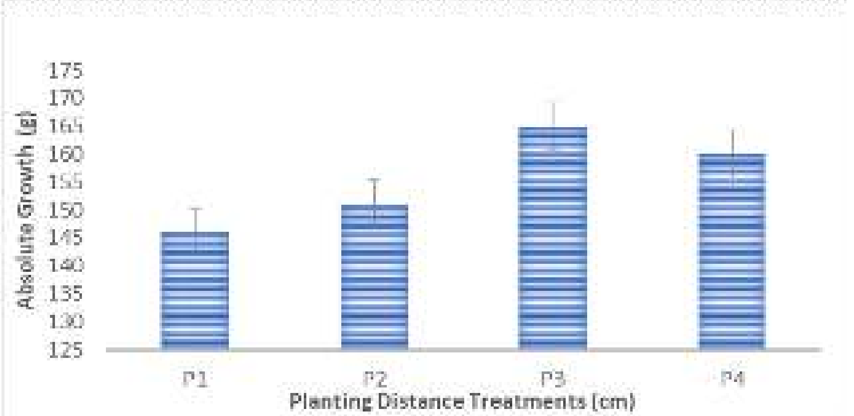

Figure 1. The absolute growth rate of seaweed *Kappaphycus alvarezii* in different planting distances (P1 (15 cm), P2 (30 cm), P3 (45 cm), and P4 (60 cm).

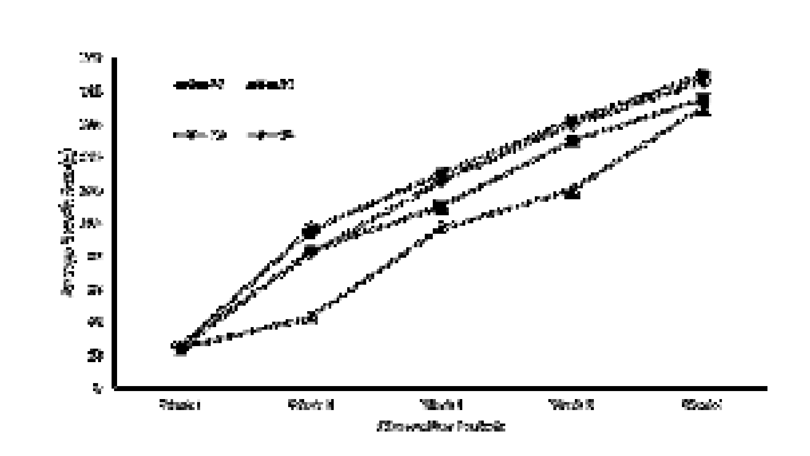

Figure 2. The average growth rate of seaweed *Kappapycus alvarezii* weekly.

Although P3 and P4 treatment statistically were the same, the P3 treatment was more effective in promoting growth (Table 1). In general, this finding indicates that the wider planting distance of seaweed, the more effective seaweed in utilizing the available nutrient into their tissue to promote optimum growth performance. This confirms with the specific growth rate data, which showed that the highest SGR (%) obtained from P3 treatment with 0.14% weekly (figure 3).

Table 1. Statistical analysis of planting distance towards the growth performance of seaweed.

Treatments	Absolute Growth Rate (g)	Specific Growth Rate (%)
P1 (15 cm)	146[a]	0.11[a]
P2 (30 cm)	151[b]	0.12[b]
P3 (45 cm)	165[c]	0.14[c]
P4 (60 cm)	160[c]	0.14[c]

Note: different superscript ([a,b,c]) indicates significant differences ($p<0.05$)

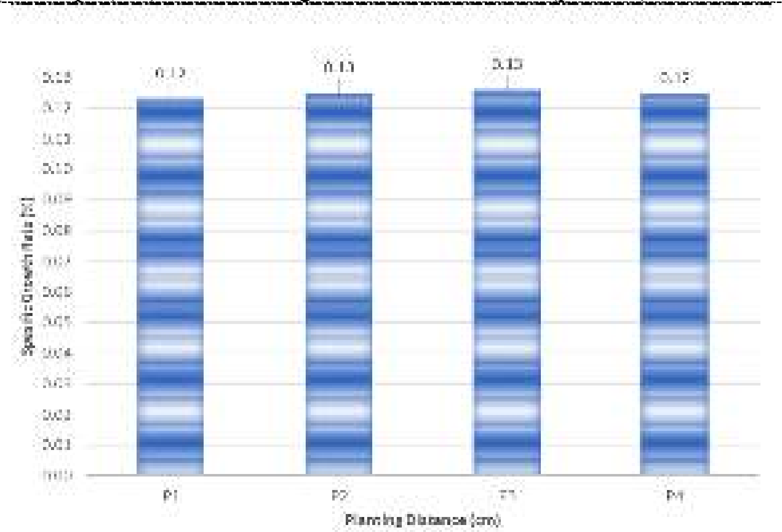

Figure 3. The specific growth rate of seaweed *Kappaphycus alvarezii* in different planting distances.

3.1.1. Water quality parameters in study sites. Water quality measurements in the study sites were conducted to determine the range of water quality that still tolerable and support the life and growth of *K. alvarezii* seaweed (table 2).

Table 2. Physical and chemical parameters of water quality in the study site.

Parameters	Ranges
Temperature (°C)	26-28.5
Salinity (ppt)	28-30.2
pH	5.1-7.2
Water current (m/s)	0.11-0.32

3.2. Discussion

The differences in planting distance of seaweed lead to different growth performance. The closer of planting distance of seaweed with one and another causes low nutrient absorption [8]. A wider planting space allows absorbing food substances in the waters as a source of nutrition. Small thallus of seaweed for seedling improve the capability of seaweed to perform self-propagation [9].

According to Abdan et al. [10], the wider the spacing, the more freely the movement of water in carrying nutrients so that accelerating the diffusion process, and if the diffusion process is accelerated, then the metabolic rate and growth rate also increased. Other factors that affect the growth of seaweed are related to the water environment, especially water quality [2,11–15]. The verticulture methods are recommended for the application of a distance of 25 cm between groups of seedlings. Furthermore, the application of 25 cm planting distance for *Gracilaria verrucosa* suggested a high growth rate and agar content [4]. Nonetheless, 50 cm of planting distance using the long-line method in fish ponds suggests a good growth rate and high yield [5].

In the present study, the environmental parameters in the cultivation site are considered still in good condition for supporting the life of seaweed according to the quality standards (Table 2). Water temperature can affect several physiological functions of seaweed, such as photosynthesis, respiration, growth, and reproduction. Chemical physics parameters of some optimal seaweeds include temperature 29.27ºC-29.68ºC [16], 26-30ºC, pH 7.47-7.80 [16], current speed 38.50-92.17 cm per sec [16], Salinity directly affects seaweed production. Low salinity leads to color changes such as the seaweed becomes pale, fragile to broken and optimal salinity for seaweed 25-31.70 ppt.

4. Conclusions

The planting distance affects the absolute growth and highest specific growth rate of Kappaphycus alvarezii. The optimum growth performance of seaweed can be obtained in a planting distance of 45 cm. The environmental parameters in the cultivation site are still suitable with the standard requirements of seaweed cultivation location.

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