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Effect of salinity on the growth of seaweed *Gracilaria changii* (Xia and Abbott, 1987)

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Abstract. *Gracilaria changii* is a seaweed species that is widely cultivated in brackish water ponds. *G. changii* cultivated in brackish waters will face high salinity problems in the dry season. This study aimed to analyse the effect of salinity on the growth of *G. changii*. The study was conducted in a controlled tank which was allowed to evaporate naturally, and without the addition of fresh water so that salinity can increase progressively. This study indicates that high salinity significantly affects the growth of *G. changii*. *G. changii* is a true euryhaline, can live at a salinity of 7 to 115 ppt. At salinity levels above 100 ppt, *G. changii* growth was negative and thallus has discoloration, but still survive. The different salinity at the beginning of cultivation produces a different maximum weight; this shows that *G. changii* can form an ecotype based on a salinity gradient.

1. Introduction

In the last 30 years, world fish consumption has grown by 122%, while world catch production has only grown by 14%. The increase in consumption in the last 30 years has been fully supported by aquaculture production which grew 527% for the period 1990-2018 [1]. This indicates that cultivation will become increasingly important in the future, and makes the cultivation sector even more important.

For the long term, sustainable aquaculture development and effective fisheries management are essential to maintain the increasing trend of aquaculture production. Therefore, there is much to be done to ensure sustainable worldwide aquaculture. Failure to implement adequate measures threatens the contribution of the fishery sector to food security and livelihoods [1]. To improve the ability to supply food from the fisheries sector, seaweed cultivation has an important role in fisheries development because the government is targeting aquaculture production of 29.9 million tons, where seaweed production is targeted at 19.54 million tons or 65% of total aquaculture production in Indonesia [2]. Seaweed cultivation is a major concern because this commodity is technically and economically more feasible to develop, especially at the level of micro and small businesses whose actors generally have a small level of skill and capital.

Seaweed cultivation in Indonesia was developed in the early 1980s. Since then, various aspects of biology [3-6], aquaculture [7-15], post-harvest handling and processing [16,17], institutional strengthening [18,19], and environmental mitigation [20-25] continues to be developed in order to support increased fishery production in Indonesia in a sustainable way.

The development of seaweed cultivation in Indonesia is practiced in the sea and in ponds in parallel. One of the most cultivated seaweed species is *G. changii* [6]. This species is widely cultivated because it has a short cultivation period, which is three to four months after planting, but after that the next harvest can be done every two months [26]. *G. changii* can be cultivated in the sea and ponds [6], but mostly cultivated in ponds.

Cultivation of *G. changii* is widely practiced in ponds because pond cultivation has many advantages over marine cultivation, including sheltered from unfavorable environmental condition such as waves, ocean currents, predators; and water quality is easier to control [27]. However, pond cultivation also has weaknesses, among others, the salinity varies greatly from very low in the rainy season to very high in the dry season. The effect of low salinity has been reported by the previous studies [28-33], however, the effect of high salinity has not yet been reported. Therefore, it is necessary to study the effects of high salinity on *G. changii*. This study aimed to analyze the effect of salinity on the growth of *G. changii*.

2. Materials and Methods

The treatment was done by using washbowls. The washbowl was 43 cm in diameter, 22 cm high. Washbowl filled with sea water as high as 20 cm; and allowed to evaporate naturally so that salinity can increase progressively. The initial salinity of sea water was 7.0 ppt (Treatment 1), 15 ppt (Treatment 2), 23 ppt (Treatment 3) and 31 ppt (Treatment 4). Each treatment was repeated three times.

The experimental design used was a completely randomized design. Each washbowl was filled with 25 g of *G. changii* as initial wet weight. Seaweed was fertilized with a commercial liquid fertilizer at a dose of 5 ppm. Cultivation was stopped when the seawater in the washbowl remained about 10 cm. Washbowls were only in direct sunlight in the morning (until 10 o'clock AM), this is intended so that the water in the washbowls were not too hot. After 10 o'clock AM, the seaweed in the washbowl receives indirect sunlight. Apart from salinity, the water quality parameters are measured were temperature, pH and dissolved oxygen.

The final average weight test of *G. changii* for each treatment used One-Way ANOVA [34]. Meanwhile, the graph of the relationship between salinity, wet weight and treatment period (days) was drawn using a trendline polynomial equation. The curve of maximum wet weight of seaweed *G. changii* related to the salinity was drawn using exponential and trendline polynomial equation on Microsoft Excel.

3. Results

During the treatment, no thallus *G. changii* was damaged, broken or died. The thallus condition was very good condition, and not brittle. At high salinity, the diameter of the thallus was smoother, but sturdier (Figure 1). High salinity (115 ppt) did not kill seaweed, but its growth was negative.

The results of this study indicate that high salinity affects the growth of *G. changii*. At the end of treatment, the wet weight of *G. changii* was significantly different ($P > 0.05$). In treatment with an initial salinity of 7 ppt, the highest weight was 53.5 g, the highest weight was reached on day 32 at 16 ppt salinity, after which, the weight began to decrease (Figure 2a). In treatment with an initial salinity of 15 ppt, the highest weight was 46 g, the highest weight was achieved at the salinity at 29 ppt, after which, the weight began to decrease (Figure 2b). In treatment with an initial salinity of 23 ppt, the highest weight was 42 g, the highest weight was reached on day 26.5 at a salinity of 40 ppt, after which, the weight began to decrease (Figure 2c). In treatment with an initial salinity of 31 ppt, the highest weight was 42 g, the highest weight was reached on day 26.8, after which, the weight began to decrease (Figure 2d). The results of this study indicate that the higher the salinity at the start of the treatment, the greater the maximum weight that can be achieved (Figure 3). Water quality parameters are within the range of values suitable for *G. changii* life (Table 1).

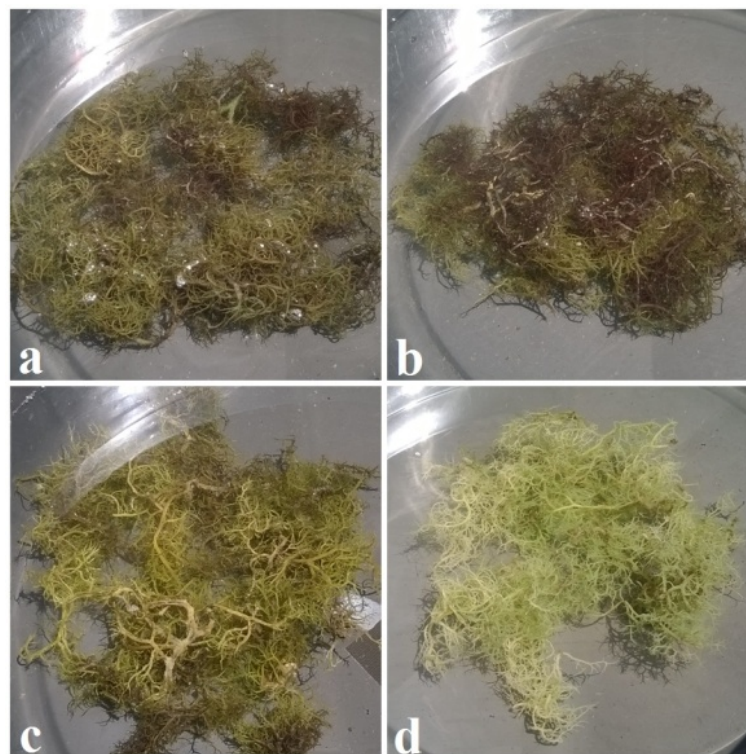


Figure 1. Seaweed *Gracilaria changii* condition at the end of cultivation. a: starting salinity 7 ppt, ending salinity 52 ppt, b: starting salinity 15 ppt, ending salinity 72 ppt, c: starting salinity 23 ppt, ending salinity 108 ppt, d: starting salinity 31 ppt, ending salinity 115ppt.

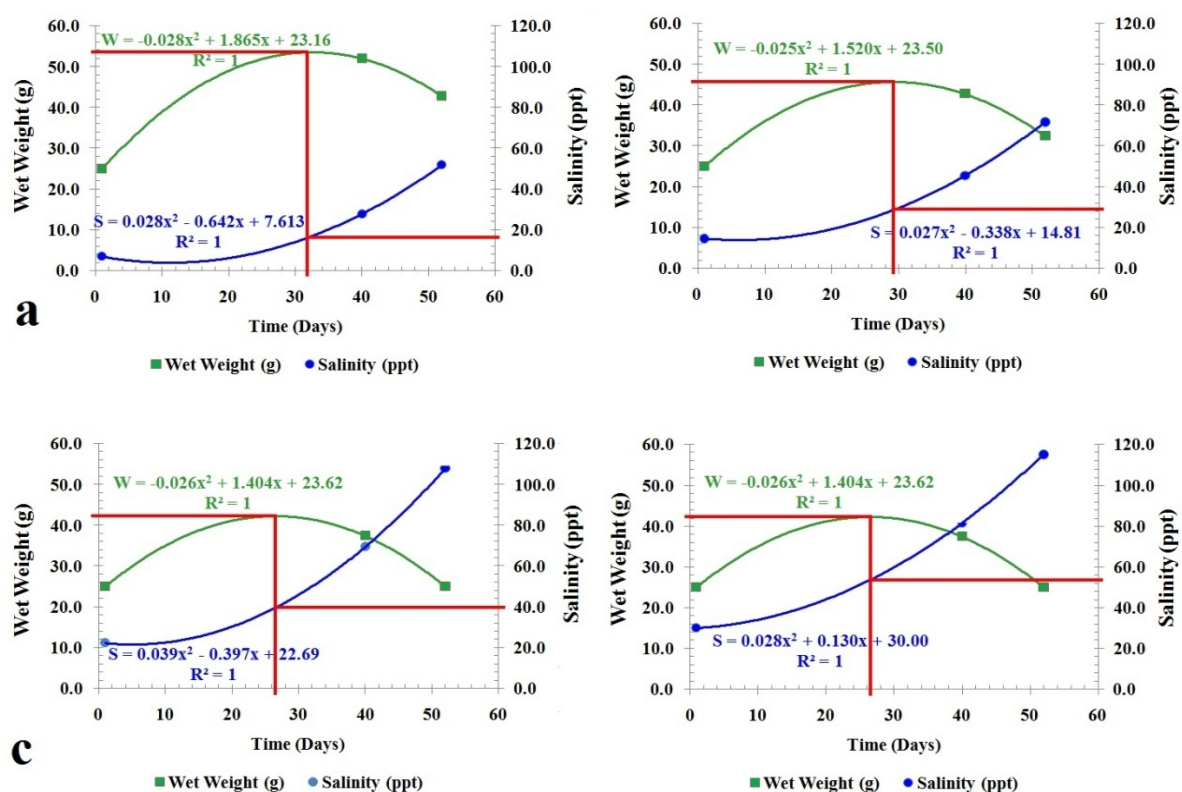


Figure 2. Wet weight growth curve (g) of seaweed *Gracilaria changii* and increased salinity (ppt) during 52 cultivation days. a: starting salinity 7 ppt, b: starting salinity 15 ppt, c: starting salinity 23 ppt, d: starting salinity 31ppt.

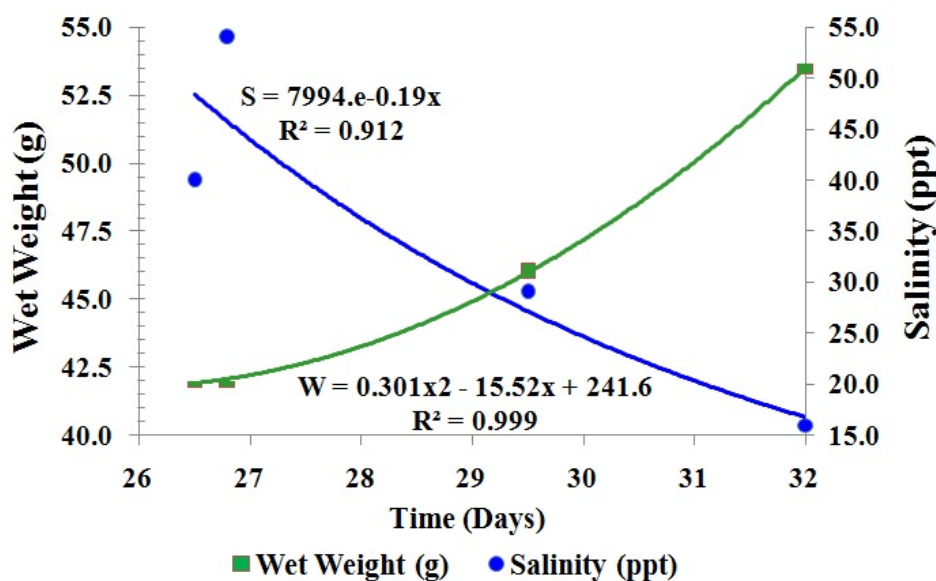


Figure 3. Curve of maximum wet weight of seaweed *Gracilaria changii* related to the salinity

Table 1. Water quality during the treatment

Parameters	Treatment 1		Treatment 2	
	Range	Mean±STD	Range	Mean±STD
Temperature (°C)	27.20-31.50	28.54±1.36	26.80-30.20	28.29±1.14
pH	7.80-8.40	8.11±0.18	7.30-8.30	7.85±0.28
Oxygen (ppm)	2.90-4.50-	3.88±0.64	1.7-4.8	3.27±1.22
Parameters	Treatment 3		Treatment 4	
	Range	Mean±STD	Range	Mean±STD
Temperature (°C)	27.00-30.50	28.46±1.14	27.20-29.90	28.46±1.01
pH	7.20-8.00	7.65±0.24	7.40-7.90	7.66±0.14
Oxygen (ppm)	1.50-4.20	2.83±1.00	2.50-4.60	3.41±0.73

4. Discussion

The results of this study indicate that *G. changii* is euryhaline that can tolerate a range of salinity variations of more than 7-115 ppt without suffering damage to its thallus. At a salinity of 115 ppt, the thallus is not damaged, only it becomes smaller and curly. At the final salinity of 115, even though the weight grows negatively, the thallus still grows, only the diameter seems smaller. Previous research has never reported that *G. changii* can survive at very high salinity, above 100 ppt. At high salinity, the thallus of *G. changii* changes color from dark green to light yellow. Previous studies have reported the effect of discoloration of thallus in *G. corticata* at a salinity of 55 ppt [35].

This study indicated that the optimum salinity may shift depending on the initial salinity of *G. changii* cultivation. This indicated that *G. changii* can perform ecological compensation to form a different ecotype as a form of adaptation to its environment. Previous studies have reported various ecological compensation performed by macroalgae as a form of adaptation to their environmental conditions, such as UV and irradiance [36], nitrate enrichment [37], temperature [36, 38], salinity [35, 36], and other environmental factor [39]. Compensation is one of three forms of biological adaptation performed by marine organisms [40]. Each compensation will produce a specific ecotype. Water

quality parameters such as temperature, pH and dissolved oxygen are in the optimal range for sea grass growth [31, 32, 41].

5. Conclusion

The results of this study indicate that high salinity significantly affects the growth of *G. changii*. *G. changii* is a true euryhaline, it can live at a salinity of 7 to 115 ppt. At salinity levels above 100 ppt, *G. changii* growth was negative and thallus suffers discoloration, but still survives. The different salinity at the beginning of cultivation produces a different maximum weight; this shows that *G. changii* can form an ecotype based on a salinity gradient.

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