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Factors Influencing the Production of Seaweed (*Kappaphycus alvarezii*) Cultivation in Waters of South Halmahera Regency, North Mollucas, Provinces, Indonesia

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ABSTRACT
The purpose of this research was to investigate the factors that contribute to the productivity of seaweed, *Kappahycus alvarezii* cultivated in the waters of South Halmahera Regency, North Mollucas Provinces of Indonesia. The study was conducted by a survey and measurement of the water parameters in each unit of cultivation area which includes depth, temperature, salinity, dissolved oxygen, a number of predatory fish, and number of aquatic plants. Culture technique (land size and number of plant spots) and social data (labours, business experience and training), were obtained by distributing questionnaires to 90 seaweed farmers. The research was conducted from May 2012 to May 2013 in three locations-Posi-Posi waters in the Subdistrict of South Kayoa, Talimau waters in Kayoa Subdistrict and Indari waters in West Bacan Subdistrict. Cobb-Douglas equation or regression model *double log*, was used to analyse the variation of some water quality parameters, cultivation techniques and social data. The result of the study indicated a number of factors determining seaweed production (R^2 = 0.640). The result of *F*-test showed that environment; cultivation technique and social variables simultaneously affected the seaweed production. The temperature was the most significant factor that influenced the seaweed production. By contrast, the lowest contribution was given by business experience.

Key words: Production, Seaweed, Cultivation, South Halmahera, North Mollucas, Indonesia

INTRODUCTION

South Halmahera is a regency in North Mollucas Provinces of Indonesia. It has a land area of 40.263,72 km^2, comprising the mainland of 8.779,32 km^2 (22%), marine of 31.484,40 km^2 (78%) and a coastline of approximately 2.384,40 km^2. The terrestrial area and the length of coastline, in fact, are very potential for marine aquaculture – particularly for seaweed cultivation (DKP, South Halmahera, 2012).
Seaweed *K. alvarezii* is a red seaweed possessing a significantly economical and multifunctional value in view of its benefits in many aspects of human life. Hence, it is deemed essential to develop this potential through cultivation (Dawes, 1995). However, a number of crucial factors need to be considered in seaweed cultivation. The productivity of seaweed cultivation is influenced not only by technical factors, but also by non-technical ones such as the social - economical level of local society, facilities and infrastructure, transportation and communication.

Production refers to a process of transforming inputs into output to increase the added values of the products (Susila and Isa, 2000). In a production process, a relationship between production factors (input) and products (output) is called production function (Soekartawi, 2003). Debertin (2012) has argued that the production function describes a technical relation of transforming input (resources) into output (commodity). The productivity of the seaweed cultivation relied highly on some production factors such as environment, cultivation techniques, social and economic. These factors are deemed important in the development of the seaweed farming (Buschman *et al*., 2008). The purpose of this research was to observe the factors influencing the production of seaweed *K. alvarezii* in the waters of South Halmahera Regency, North Mollucas Provinces, Indonesia.

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MATERIALS AND METHODS

Study area

The study was conducted at South Halmahera Regency which is located between east longitude 126° $45^1$and 129° 30^1 and north latitude 0° 30^1 and south latitude 2° 00^1. The borders of South Halmahera Regency are as follows: Tidore Island and Ternate city in the north, Seram sea in the south, Halmahera sea in the east and the Maluku Sea in the west.

South Halmahera Regency has an air temperature range of 21-31ºC or average 26,40ºC, relative humidity range 7of 0–90%, and air pressure range of 10,067-10,103 mm, wáter wave height of about 50 cm – 132 m, wave velocity 4.9 seconds, average rainfall of about 18,248 – 2,555 mm (DKP, South Halmahera, 2012). This research was conducted by a survey and measurement of the environmental variables in each unit of cultivated areas. Aquatic environment factors investigated comprised of water depth (cm), temperature (ºC), salinity (ppm), dissolved oxygen (mg/L), the number of predatory fish and aquatic plants. The water depth was measured using calibrated polyethylene (PE) ropes attached to a sinker, temperature using Eutech Instruments (Model: PCD 650), salinity using, hand refractometer, dissolved oxygen using Eutech Instrument Cyberscan DO meter (Model: PCD 650), aquatic plants by iron quadrant (1x1 m^2), predatory fish was measured using fishing gill net (2.5 inch mesh). The culture, land area and number of plant supports and social economic data (labour, business experience and training) were collected through distributing questionnaires to 90 seaweed farmers. The study was conducted for the period of one year (May 2012 to May 2013) in three locations; - Posi-Posi voters in the Sub - district of South Kayoa, Talimau waters in Subdistrict of Kayoa, and Indari waters in the Sub-district of West Balkan (fig 1).

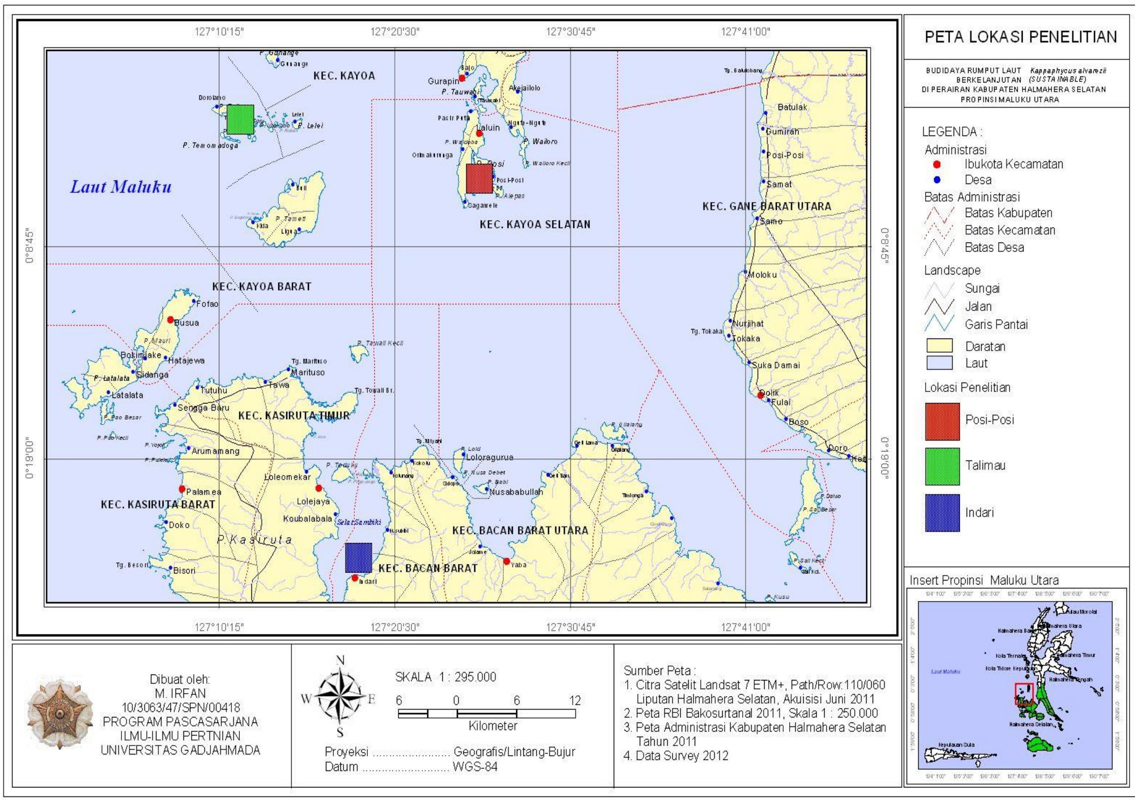

Figure 1. Map of North Mollucas Provinces, showing the study area.

Water quality parameter, cultivation technique and social-economic data were analysed using the equation model of production function Cobb-Douglas or regression model of *double log* (Soekartawi, 1990; Shang, 1990) using the following formulae:

$Y = b_{0.}x_1b_1x_2b_2x_3b_3x_4b_4x_5b_5x_6b_6x_7b_7x_8b_8x_9b_9x_{10}b_{10}x_{11} + \delta_1\text{Season} + \delta_2\text{Location}_1 + \delta_3\text{Location}_0 + U$

To calculate the parameter of b_1-$b_{11,}$ the equation could be modified into the following linear regression.
$LnY = Lnb_0 + b_1Lnx_1 + b_2Lnx_2 + b_3Lnx_3 + b_4Lnx_4 + b_5Lnx_5 + b_6Lnx_6 + b_7Lnx_7 + b_8Lnx_8 + b_9Lnx_9 + b_{10}Lnx_{10} + b_{11}Lnx_{11} + \delta_1 Season + \delta_2 Location_1 + \delta_3 Location_0 + U$, Where:

Ln = Logarithms natural
Ln Y = number of production (kg)
b= Ln b_0 = intercept
b_1-b_{11} = regression coefficient
Ln x_1 = land area (m^2)
Ln x_2 = number of plant spot (unit)
Ln x_3 = business experience (year)
Ln x_4 = training (number/year)
Ln x_5 = labour (working day of people)
Ln x_6 = depth of waters (m)
Ln x_7 = temperature(^{0}C)
Ln x_8 = dissolved oxygen (mg/l)
Ln x_9 = salinity(‰)
Ln x_{10} = number of fish predator (ind)
Ln x_{11} = number of aquatic plants (ind)
$\delta_1$season = valued 1 for dry season
valued 0 for rainy season
$\delta_2$location1 = valued 1 for the samples from Posi-Posi
valued 0 for the samples from any locations except Posi-Posi
$\delta_3$location0 = valued 1 for the samples from Talimau
valued 0 for the samples from any locations except Talimau
U = error term

The model accuracy was tested using coefficient of determination or R-squared R^2) value that indicated the level of dependent variables as explained by the independent variables in the model (Gujarati, 1997).

R^2 = (ESS/TSS) = 1 - (RSS/TSS)……………………………………………(1)

where :
R^2 = coefficient of determination values
ESS = *explained sum of squares*
TSS = *total sum of squares*
RSS = *residual sum of squares*

It was then continued with F-test and t-test. F-test was conducted to find out whether the independent variables simultaneously influential on the dependent variables. F-count (Gujarati, 1997) was determined using the following formula:

F-count = $[(R^2)/(k-1)]/[1-R^2)/(n-k)]$…………………………………………………………….(2)

F-table= [(k-1); (n-k); σ], where:
k = the number of regression coefficient including intercept
n = the number of samples

Meanwhile, t-test was to figure out the influence of each independent variable on the dependent variables. The values of t-count and t-table were formulated as follows:

t-count = β√Sßi ………………………………………………………………………(3)

t-table= (n-k; σ/2)

where
βi = estimated parameter
Sβi = estimated *standar error* parameter
n = number of samples
k = number of independent variables

RESULTS

Regression Analysis on the production function of Seaweed *K. alvarezii* in South Halmahera Regency

The factors influencing the production of seaweed cultivation could be categorized into the environmental, technical, and social variables.

Table.1 Regression analysis on the production function of Seaweed *K. alvarezii* in South Halmahera Regency

Variable	Expected Sign	Coefficient	Standard Error	t-ratio	Probability	Sign
Constant	-	-2.253	3.147	-0.609	0.512	ns
Water quality parameters						
Ln_Depth	+	0.159	0.050	3.158	0.002	**
Ln_Temperature	+	1.004	0.597	1.681	0.097	*
Ln_Dissolved Oxygen	-	0.065	0.236	0.276	0.783	ns
Ln_Salinity	+	0.952	0.802	1.187	0.239	*
Ln_Number of fish Predators	-	-0.243	0.094	-2.599	0.011	ns
Ln_Number of aquatic Plants	+	0.385	0.095	4.038	0.000	**
δ_1Season	+	0.129	0.049	2.660	0.010	**
δ_2Location1	+	0.130	0.058	2.241	0.028	**
δ_3Location0	-	0.018	0.052	0.341	0.734	ns
Technique						
Ln_Land Area	+	0.154	0.042	4.389	0.000	**
Ln _Number of plant spots	+	0.888	0.122	7.270	0.000	**
Social-economic						
Ln_Business Experience	-	0.011	0.069	-0.161	0.872	ns
Ln_Training	-	-0.021	0.064	-0.333	0.740	ns
Ln_Labour	+	0.116	0.050	2.321	0.023	**

ns = not significant, * significant at 1% level error, ** significant at 5% level error

The coefficient of determination value (R^2) of 0.640 (64%) indicated that the contribution of both independent variables, including some water quality variables (depth, temperature, dissolved oxygen, salinity), number of predatory fish, number of aquatic plants, δ_1 season, δ_2 location$_1$ and cultivation technique (land area, number of plant spots), and social-economic variables (business experience, training, and labour) could be explained in the model of the dependent variables (Ln_production). Meanwhile, the 36% of the rest were explained and influenced by other variables outside variable X or out of the model.

The probability values indicated that F values (0.05) were profoundly influential (0.000 < 0. 05). The value of F-table in the probability of 0.05 was 1.986 that indicated that the value of F-count > F-table (9.533 > 1.986). Thus, all independent variables–water quality parameters, culture, technique, and social-economic variables simultaneously influenced seaweed cultivation. Furthermore, the result of *t*-test revealed that the independent variables; water depth, temperature, salinity, number of aquatic plants, $\delta_1$season, $\delta_2$location1, and labour partially significant towards the dependent variables. In contrast, other independent variables; dissolved oxygen, a number of predatory fish and δ_3 location0, business experiences and training were not significant to the dependent variables.

The probability of the Ln_depth variable was 0.002 below 0.005 (at 5% error level). Hence, this variable was influential on Ln_production of seaweed cultivation. Meanwhile, the regression coefficient of Ln_depth was 0.159 showing potentiality by the addition of 1-meter in depth to develop Ln_production of seaweed cultivation, which accounted for 0.159 kg. On the other hand, the probability of Ln_temperature variable was 0.097 below 0.05 (at 5% error level). Hence, the variable of Ln_temperature was influential on the Ln_production of seaweed cultivation. The regression coefficient of Ln_temperature was 1.004, showing potential by adding temperature to develop Ln_production of seaweed cultivation (1.004 kg). The probability of Ln_salinity variable was 0.239 below 0.05 (at 5%error level) Thus, this variable was influential on Ln_production of seaweed cultivation. In addition, regression coefficient of Ln_salinity of 0.952 showed that the addition of one unit of salinity was potential to increase the Ln_production of seaweed cultivation accounting for 0.952 kg. For the variable of Ln_number of aquatic plants, probability was 0.000 below 0.05 (at 5% error level). Thus, it showed that the variable of aquatic plants number was also influential on Ln_production of seaweed cultivation. The regression coefficient of Ln_Number of aquatic plants was 0.385 and indicated the potential of the increase of Ln_production of seaweed cultivation (0.385 kg) coincided with the increase of the number of aquatic plants. The probability of δ_1 seasonal variable was 0.010 below 0.05 (at 5% error level); thus, this variable was highly influential on Ln_production of seaweed cultivation. The regression coefficient of $\delta_1$season was -0.129, indicating that if it was increased, it could be very potential to increase Ln_production of seaweed cultivation (0.129 kg). Furthermore, the probability of the location variable was 0.028 below 0.05 (at 5% error level). It showed that the variable of δ_2 location1 was influential on Ln_production of seaweed cultivation. The regression coefficient of location1 was 0.130, showing that the addition of location was very potential to increase Ln_production of seaweed cultivation (0.130 kg).

Meanwhile, the probability of the variable of Ln_land area was 0.0000 below 0.05 (at 5% error level). This then showed an impact of this variable on Ln_production of seaweed cultivation. In addition, the regression coefficient of Ln_land area was 0.154 indicating that every addition of 1 m^2 land area could be potential to increase Ln_production of seaweed cultivation (0.154 kg). For the variable of Ln_number of plant spots, the probability was 0.000 below 0.05 (at 5% level error); thus there was an impact of on Ln_production of seaweed cultivation. The regression coefficient of Ln_number of plant spots was 0.888, indicating the potential to increase Ln_production of seaweed cultivation (0.888 kg) if the number of plant spot was added.

The probability of the variable of Ln_labour was 0.023 below 0.05 (at 5% error level). Therefore, the variable of Ln_labour was influential on Ln_production of seaweed cultivation. The regression coefficient value of this variable was 0.116 showing that each addition of one working day of people accounted for 0.116 kg potential to increase Ln_production of seaweed cultivation. Table 2 below presents the contribution of independent variables towards the production level of seaweed *K. al*varezii cultivation.

Table 2: Result of the analysis on the contribution of independent variables towards the production of Seaweed cultivation in the waters of South Halmahera Regency

Variables	**Coefficient**	**Contribution Ranks**
Water quality parameters		
Ln_Depth	0.159	5
Ln_Temperature	1.004	1
Ln_Dissolved Oxygen	0.065	9
Ln_Salinity	0.952	2
Ln_Number of fish Predators	-0.243	11
Ln_Number of aquatic Plants	0.385	4
δ_1Season	0.129	12
δ_2Location1	0.130	7
δ_3Location0	0.018	10
Technique		
Ln_Land Area	0.154	6
Ln _Number of plant spots	0.888	3
Social-economic		
Ln_Business Experience	0.011	14
Ln_Training	-0.021	13
Ln_Labour	0.116	8
Total	3.747	

The result of the contribution of each independent variable (Table 2) showed that the environmental variable (temperature) with the highest value of the regression coefficient (1.004) was ranked first for providing the highest contribution to seaweed production. It was followed by salinity a ranked second and culture technique variable; i.e. number of plant spots were at the third rank with regression coefficient values of 0.952 and 0.888, respectively. In contrast, the lowest contribution was found from social-economic variable (business experience) which ranked 14th with a regression coefficient value of -0.021. The contribution of each independent variable to the production of seaweed cultivation in the research study area sequentially included temperature, salinity, number of plant spot, number of aquatic plants, depth, land area, $\delta_2$location 1, labours, dissolved oxygen, $\delta_3$location0, the number of predatory fish, $\delta_1$season, training and business experiences.

DISCUSSION

Water quality parameters

Water depth that can increase seaweed production is the one that allow sunlight penetration. Water depth is highly related to sunlight penetration required for seaweed growth (Mappatoba *et al*., 2010). The water depth for the cultivation of *K. alvarezii* ranges from 4 to 17 m (Khan and Satam 2003), 5-25 m (Kangkan *et al.*, 2006). Hence, the water depth for the seaweed cultivation in the research locations (2 to 8.5 m in this case with the average of 14.6 m) was still suitable to the depth condition required by seaweed. In this way, the depth could affect seaweed production. It was likely due to the existence of the strong wave on the water surface making the depth under the waters silent and enabling the sunlight to penetrate to the floor of the waters.

Temperature also contributed to influencing the seaweed – particularly in metabolism since the metabolism acceleration increased coincided with the increase of the water temperature (Lobban and Harrison 1997). An optimal temperature could improve the process of absorbing the nutrients that, in turn, enabled the seaweed growth to be faster in view of the smoothness and rapidity of the metabolism (Effendi 2000). In addition to that, the temperature could be influential on the physiological function of seaweed such as for photosynthesis, respiration and reproduction (Dawes 1995). Noted, the optimal temperature for seaweed cultivation ranged from 20 to 32ºC (De San 2012). The measured temperature in each unit of seaweed cultivation area, meanwhile, ranged from 27.9-31ºC. Here, the obtained temperature was still in agreement with the temperature as required in seaweed cultivation. Thus, it could improve seaweed production.

Salinity, meanwhile, played a very essential role in the growth and development of seaweed for being directly related to osmoregulation occurred in cells (Lobban and Harrison 1997). The different thickness between the liquid inside and outside cells could stimulate the golgy body to keep on attempting to make it balanced; thus becoming isotonic. This then impacted by the use of larger energy and the low growth and development of seaweed. The high salinity could make golgy body incapable of balancing the liquid concentrate on cell with the concentrate of liquid outside the cells. This, at last, could result in more cells, liquid absorbed into the environment and make the cells smaller than their previous size (Arisandi *et al*., 2011). Salinity required by seaweed *K. alvarezii* must be in the range of 33-35‰ Arfah and Papalia (2008), 18-35‰ (Lobban and Harisson 1997). The salinity measured in the areal unit of seaweed cultivation in the research location (32-35‰) was still suitable for the cultivation of the seaweed; thus enabling to develop the production.

Meanwhile, the aquatic plants were influential in the production of seaweed cultivation as its existence around the location of the seaweed cultivation came to be one of the important indicators that the location was suitable to be used as the location of the seaweed cultivation. The aquatic plant is an organism that is capable of doing the photosynthesis process. In this way, the presence of the aquatic plants such as *lamun* and *algae* was very essential to support the life of the cultivated seaweed (Drying, 1982; Dawes, 1995; SEAFDEC, 2006).

The seaweed growth can be various in responding season. *K. Alvarezii* can grow well in dry season; thus increasing the production. Conversely, it grows slowly in rainy season and, in view of this, it can decrease the production (Msuya and Salum, 2007). It is because wind and wave in the rainy season can be larger and make the seaweed damaged and delicate; than severely impacting on production (Sievanena *et al*., 2005).

Furthermore, the location also impacted on seaweed production in view of the good management of the waters in the physical and chemical aspects and other aspects such as the availability of labours in the location. In other words, the management has fulfilled the requirements as the location for seaweed cultivation enabling seaweed to grow well and to contribute to the production increase.

Culture technique variable

For cultivators, land area refers to an asset in yielding the total production and income. The wider the land area used, the more optimal the production yielded. Hence, with the productive land, the cultivators tend to have the highest income and can develop their business with sufficient capital (Batoa *et al*., 2008). The condition in the research location showed that the land area of the cultivators (250 to 2500 m^2) was considered sufficient to give a positive contribution to the increase of seaweed production.

The number of plant spots with an accurate planting distance could increase the production as the planting distance was tightly related to competition of each seaweed to obtain nutrients as its food (Pongarrang *et al*., 2013). Additionally, the planting distance was also influential on the water movement to prevent the waste deposited on *thallus* functioned to support the airing to prolong photosynthesis required for the seaweed growth (Abdan *et al*., 2013).

The narrower planting distance and the lighter initial weight of seeds were able to make the distance narrower among the planting spots. As a result, it could have more planting spots per surface-unit and then made the production yielded more optimal. Conversely, a wider planting distance could cause the planting spots fewer and made more planting spaces unused. This then made the production not optimal (Setiyanto *et al*; 2008 in Insan *et al*., 2013). The planting distance that can give the best production of seaweed should be in the range of 20-25 cm with the total initial weight of seed of 50-100 g (Department of Marine and Fisheries 2009). Abdan *et al*. (2013) explained that the planting distance of 30-40 cm with 50 g of the initial weight of seed still increased seaweed production. On the other hand, Pongarrang *et al*. (2013) viewed that the planting space ranging from 15 to 20 cm with 100 g of initial weight could increase seaweed production. In turn, the condition of research, location revealed that the planting distance (15-40 cm) with 50-100 g of initial seed weight was still in the required condition regarding seaweed cultivation; thus it could increase seaweed production.

Social-economic variable

Labour refers to the energy given in a process of activity to result in a product. Human labour (man, woman or children) could be from inside or outside family (Shinta, 2011). Labour can be very influential in seaweed production in consideration to that the addition of its number could create better business management of seaweed cultivation. The labour recruitment can also escalate the number of job opportunities in seaweed cultivation. By increasing the number of the labours, there will be more number of the labours to be employed for seaweed cultivation business.

The average of the number of paid labour from outside family was varied (1 to 7 people), in which the work mainly dealt with plant cultivation, such as waste/adhered mud removal, seed cordage, replacing the detached seeds, replacing float and detached anchor and harvesting. The number of labours was highly dependent upon the land area being used. In research location, the number of the labours as previously mentioned increased seaweed production.

Contribution of each independent variable to seaweed production

Temperature provided the highest contribution to seaweed production as it had the highest value of the regression coefficient. It was proven that it was capable of increasing seaweed production in that the temperature range obtained was in agreement with need of seaweed growth. A very specific range of temperature in seaweed growth was related to its enzyme disfunctional at a very cold or hot temperature (Dawes, 1995). In this case, the higher temperature of waters could lead to the death of seaweed, damaged enzymes and unstable membranes. The temperature increased coincided with the increase of sun energy entering into the waters and then increased the rate of photosynthesis until certain radiation (Lobban and Harisson 1997). At this point, the maximal rate of photosynthesis of *K. alvarezii* was at 30ºC. In contrast, the activity of photosynthesis was hindered at the temperature above 32ºC (Munoz *et al*., 2004). Nutrient membranes and fat at a lower temperature could experience damage a result of the formation of the crystal in the cell. This then impacted on seaweed (Luning, 1990).

Social-economic variable (business experience) was ranked 14 in view of its low contribution to seaweed production. This variable had a low regression coefficient value, making it unable to increase seaweed production. In common, the business experience of seaweed cultivation in the research location was on the average of 3.2 years in which it has not increased the seaweed production yet. Hence, the business experience of cultivators needs to be improved in the future with more frequently joining trainings related to seaweed cultivation. Sambo *et al*. (2000) said that, to improve the business experience of seaweed cultivators, an attempt to establish a counselling is essential to make the cultivators understand more and able to improve their capacity - particularly in managing the pattern of planting time, seed, harvesting time and post-harvesting time accurately in their area. For this, there should be a test of seaweed cultivation in order to catch a real description about the result of qualified production in accordance with the market demand both for the quality, quantity and continuity.

Conclusion

The factors influencing the production of seaweed *K. alvarezii* included depth, temperature, salinity, number of aquatic plant, season, land area, number of plant spots and labour. In this case, temperature provided the highest contribution to the production of seaweed. By contrast, the variable of business experience provided the lowest contribution to the production.

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