Brown Seaweed (*Sargassum polycystum* L) Extract Utilization to Improve Cucumber (*Cucumis sativus* L.) Crop Yield on Acidic Dry Soil

(Pemanfaatan Eksrak Rumput Laut Coklat untuk meningkatkan hasil tanaman Timun di Lahan Kering Masam)

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Abstract
Many efforts to invent biological materials serving to be fertilizer and soil ameliorant have been being continuously conducted nowadays in order to enhance marginal soil productivity. That fertile area gets decreasing result of land conversion to non-agricultural use and degradation result to intensive use of artificial fertilizers, land productivity keeps decreasing. Its adverse impacts should not be ignored. However, with various biological materials inventions which may be utilized as sources of plant nutrition and to ameliorate soil's chemical, physical and biological properties, the problem may be coped with. In this case, brown seaweed (Sargassum polycystum L.) is economically less profitable as functional food material draws attention. This type of seaweed may be utilized as a substrate to fertilize the soil. The purpose of this research is to study the influence of brown seaweed extract as a source for plant nutrition and its solid material as a soil ameliorant. The research results show that brown seaweed extract may enhance cucumber crop growth and yield when applied to acidic dry soil.
Keywords: *brown seaweed extract, cucumber, dry soil*

Abstrak
Dewasa ini upaya penemuan bahan hayati sebagai pupuk dan pembenah tanah dalam rangka meningkatkan produktivitas lahan marginal terus ditingkatkan. Seiring lahan subur makin sempit akibat alih fungsi ke non pertanian dan terdegradasi akibat penggunaan pupuk buatan secara intensif. Dampak buruknya tidak bisa diabaikan. Produktivitas tanah semakin menurun. Namun demikian dengan ditemukannya berbagai bahan hayati yang dapat dimanfaatkan sebagai sumber hara untuk tanaman sekaligus memperbaiki sifat kimia, fisika dan biologi tanah. Maka masalah tersebut dapat ditanggulangi. Perhatian terarah ke rumput laut coklat (*Sargassum polycystum* L.) yang secara ekonomis kurang menguntungkan sebagai bahan baku pangan fungsional. Jenis rumput laut ini dapat dimanfaatkan sebagai substrat menyubur tanah. Tujuan penelitian mempelajari pengaruh ekstrak rumput laut coklat sebagai sumber hara tanaman dan bahan padatnya sebagai amelioran tanah. Hasil penelitian menunjukkan bahwa ektrak berbahan rumput laut coklat dapat meningkatkan pertumbuhan dan hasil tanaman Timun yang diaplikasikan di tanah kering masam.
Kata kunci: ekstrak rumput laut coklat, ketimun, lahan kering masam

I. Introduction

Dry acid soil utilization in most Indonesian areas faces problems in achieving optimal agricultural productivity. Dry soils in Indonesia are generally included in Ultisol order, 148 ha in size (Mulyani *et al*, 2004), which is one marginal soil that may be engineered to be arable soil.

The size of Ultisol is up to 45.9 million ha or 24.3 % of the Indonesian land surface (Subagyo *et al.*, 2000) distributed in Kalimantan, Sumatera, Maluku and Papua, Sulawesi, Java and Nusa Tenggara. This soil may be found in various reliefs, from plain to mountainous land (Prasetyo & Suriadikarta, 2006). Acidic dry soil is formed with relatively high rainfall which causes a relatively intensive level of base cations leaching, which makes low content of base cations. This condition stimulates the dominant activity of H^+, $Fe^{2+,}$ and Al^+ ions on the exchange complex, thus lowering soil pH and causing soil's acid reaction. However, the chance to develop agriculture in this dry acid soil remains high by engineering acid conditions to reach a nearly neutral pH (Yang et al, 2013; Rahman et al, 2018; Yadesa et al, 2019). This is made with organic matter fertilization rich in base content and treatment using liquid organic fertilizer rich in macro and micronutrients, like using wild seaweed material as organic matter in the form of compost or its liquid fertilizer (Latique et al, 2013; Michalak et al, 2017).

Until today, brown seaweed utilization is, particularly in Indonesia, generally limited to food products and semi-finished products like *agar kertas*, alkali-treated cottonii (ATC), jelly-product and some cosmetic products. Only a few researches have been conducted on the biological functions of seaweed extract to stimulate plant growth in enhance harvest (Zahid, 1999). In other countries such as Australia, France, the UK, India, Japan, New Zealand, Scotland, Spain, and America, seaweed has been long known to be plant fertilizer (Zahid, 1999; Smith and Ross, 2016).

Brown seaweed may also be utilized as fertilizer (Jufri *et al.*, 2010). There are 88 species of seaweed found in Indonesian sea waters, five species of which may be potentially developed to be fertilizers and natural growth stimulators (Nikmatullah *et al.*, 2014). Some of the seaweeds include *Sargassum polycystum, Sargassum binderi, Sargassum sinereum, Sargassum duplicatum, Sargassum plagyophyllum*, and *Sargassum craccifolyum*. One of the six species, the type of seaweed *Sargassum polycystum* L., has no economic value but freely grows on rocky areas for about six months, and then is released and stranded on beaches (Anggadiredja *et al*, 2010; Begum et al, 2018)). This type of seaweed (*Sargassum polycystum* L.) may be utilized as environmentally-friendly organic fertilizer (Anggadiredja *et al*, 2010; Trejo et al, 2018).

Seaweed has been long, directly used to be soil ameliorant and fertilize in many coastal areas in the world (Van Overbeek, 1940; Wu and Lin, 2000; Sedayu, 2014) and seaweed extract has been marketed as an additive to plant fertilizer with many reported benefits and advantages (Sedayu *et al.* 2011). In addition to containing important minerals from the sea needed by plants, seaweed also has growth stimulator hormone content proven to improve plant growth and harvest (Sivansankari *et al.* 2006). Unlike chemical fertilizer, seaweed extract is biodegradable, non-toxic, non-contaminant, and safe for humans and animals (Sivansankari *et al.* 2006; Ziegler et al, 2016). Seaweed utilization as fertilizer or fertilizer additive is expected to be an alternative to solve environmental problems since it is safe for soil and plant microbes and may enhance Indonesian seaweed's economic value (Sedayu *et al.* 2011; Hafting et al, 2015). The purpose of this research is: to study the influence of seaweed as a substrate material to improve nutrient availability and plant yield on dry acid soil.

II. Materials and Methods

2.1. Material Preparation

The research is conducted at the general laboratory of Universitas Darussalam Ambon, located at Morela, 18 km from the campus. The analysis of the properties and nutrient content of soil and brown seaweed tissue is conducted at the Soil Science Laboratory, Faculty of Agriculture, UGM. This research is conducted for 5 months with 2 series of studies.

2.2. Data Analysis

The research is conducted in two series, the first of which is making seaweed extract for liquid fertilizer, with materials and mechanism as given in (Figure 1). Soil analysis: pH H_2O (pH meter), C-organic % (Walkey & Black Titration, Dry destruction), CEC cmol(+)kg^{-1}) (AAS/NH_4OAc 1 N pH 7), N-total % (Kjeldahl), P-potential ppm (Extract HCl 25%), P-available ppm (Bray I/ Spectrophotometer), K-potential (Extract HCl 25%), Cations available: K, Ca, Mg, Na (cmol(+)/kg) (Extract NH_4OAc 1 M pH 7/SSA).

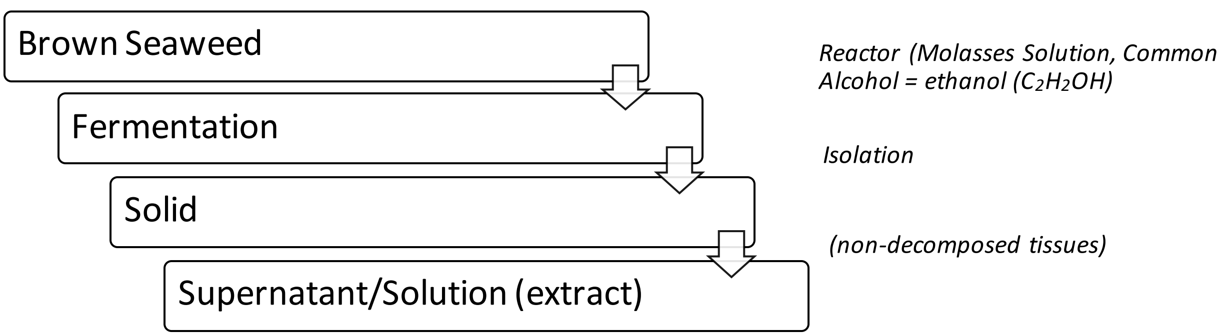

Figure 1. Simple method brown seaweed extract making process

The second series is the application of seaweed-based solution as liquid fertilizer to cucumber plants in the field for 3 months. Observation of vegetative growth and some generative variables is conducted with the following research method: this research is designed using Randomized Block Design (RAB) with one factor: brown seaweed extract (*Sargassum polycystum* L.) consisting of 5 (five) levels of treatment: S_0: without basic fertilizer and extract, S_1: without extract treatment, S_2: 25cc /l water, S_3: 50 cc/l water S_4: 75 cc/l water, S_5: 100 cc/l water. There are 5 levels of treatment and 3 repetitions of the experimental unit. Each unit consists of 6 plants, with a total of 90 observation units. The observational variables are Vegetative growth (plant height and leaf formation), Generative growth (flower, fruit), and Economic variable (Fruit length, Fruit diameter). The data resulting from observation are tested using F-test α=5%.

III. Result and discussion

The data resulted from the acid soil analysis, in this case, Ultisol, show that this soil condition is infertile (Table 1). The Ultisol soil taken as the growth medium in this research has pH 4.87 and is acid-reacting, which causes the Al-dd content to increase and, thus, P anions get locked up (Latuponu, *et al*, 2012). This is reflected by P-total content which is only 745 ppm with quite low P-available 1.22 ppm, which is the main problem for Ultisol soil. This condition is strengthened by soil CEC which is only 12.67 cmol(+)/kg, and consequently, the base cation-exchange capacity is low. The content of cations K-dd (0.487 cmol(+)/kg); Ca-dd (0.47 cmol(+)/kg); Mg-dd (0.54 cmol(+)/kg); Na-dd (0.47 cmol(+)/kg) makes this soil poor of nutrients available for plant. The C-organic content is also low, only about 1.13%, causing Al-dd saturation to increase. Although the carbon-nitrogen ratio is of medium valence, about 10, it has caused this soil infertile.

This condition reflects that the soil is dominated by kaolinite minerals with the soil's red matrix color as the result of iron hydroxide and oxide and humus dispersion. Chunky and sticky structure and consistency are the characteristics of Ultisol soil (Ismangil 2008). Ultisol's high clay diffraction makes soil's volume weight (BV) high, and thus it is difficult to cultivate as a result of soil's sticky and solid particles. This disadvantages root movement. Although its water content is high, most of the soil's pores are filled with water, and, on the other hand, air pores get decreased, thus water may not be maximally utilized by plants.

Table 1. Results of Analysis on acid soil's (Ultisol) nutrient properties and contents

Acid Soil (Ultisol)	Unit	Value	*Valence
pH H_2O	-	4.87	Acid
KPK (Cation-Exchange Capacity)	cmol(+)/kg	12.67	Low
C-organic	%	1.13	Low
C/N	-	10	Medium
N-total	%	0.13	Low
P-total	ppm	192.12	Quite low
P-available	ppm	1.22	Quite low
K-dd (Potassium is exchangeable)	cmol(+)/kg	0.48	Low
Ca- dd (Calcium is exchangeable)	cmol(+)/kg	0.47	Quite low
Mg-dd (Magnesium is exchangeable)	cmol(+)/kg	0.54	Quite low
Na- dd (Sodium is exchangeable)	cmol(+)/kg	0.47	Medium

Table 2. Results of Analysis of Seaweed (*Sargassum polycystum* L.) Fiber content

Brown Seaweed Tissue	Unit	Value	*Valence
pH H_2O	-	6.8	Neutral
C-organic	%	19.8	Low
N total	%	2.02	Medium
P_2O_5 total	ppm	745	Low
K_2O total	ppm	708	High

*Approach: Xia et al, 2012.

The description of soil conditions as reflected in the analysis result data in Table 1 means that utilizing the Ultisol soil as a plant growing medium requires organic materials and nutrients input to enhance its fertility. The results of the analysis on brown seaweed (*Sargassum polycystum* L.) tissue (Table 2) show that this seaweed, with neutral-reacting pH 6.8, may be utilized as soil ameliorant with the application of its decomposed fiber in the form of compost biochar (biological charcoal). This brown seaweed may also be applied to soil in liquid form (extract) as liquid fertilizer since its low valence C-organic content, about 19.8%, may enhance the soil's cation-exchange capacity. This liquid application is not directly sprayed to the plant, but given to the soil to quickly supply nutrients to the plant and to be soil ameliorant. Brown seaweed, serving to be the source of nutrient containing N-total (2.2%) (Table 2) derived from the brown weed tissue with the liquid application (extract), will facilitate the nitrification process with the release of NO_3^- anion and ammonification with the release of NH_4^+ cation (Fageria *et al*, 2011; Latuponu *et al*, 2011; Taiz and Zeiger, 2002) to be absorbed the by the plant. The P-total (745 ppm) nutrient in this brown seaweed tissue has shown that the material is appropriate to be made substrate to produce liquid fertilizer through a certain enriching process. The same also takes place with Potassium (K) nutrient of 708 ppm (Table 2). These three nutrients are the main macronutrients needed by plants in a large quantity. When these three nutrients are fulfilled, it is expected that micronutrients deficiency will be easy to solve.

Table 3. Influence of giving brown seaweed extract to some observation variables of cucumber plant

Treatment	Cucumber plant observation variables					
	Plant's Upright Height (cm)	Mature Leaves (Sheets)	Flower	Harvest Fruit	Fruit diameter (cm)	Fruit length (cm)
S0	72.00 b	12.72 b	7.22 c	5.00 c	1.50 b	20.50 c
S1	97.83 ab	14.28 ab	10.72 b	6.00c	1.94 b	21.60 c
S2	92.34 a	16.22 ab	14.39 a	8.00 b	2.22 b	22.08 b
S3	102.06 a	16.28 ab	15.55 a	9.00 ab	3.5 a	22.99 a
S4	113.94 a	19.28 a	17.28 a	10.00 a	4.00 a	23.65 a

Explanation: numbers followed with the same letter in column are insignificantly different (α=5%), DMRT.

The appropriateness of brown seaweed extract application to Ultisol soil (Acid soil) shows positively as indicated by the data (Table 3). The response of the cucumber plant's vegetative and generative variables as the research's indicators significantly increases after brown seaweed extract application. The growth rate varies and shows an increase in line with the quantity of brown seaweed extract treatment (0, 25, 50, 75, 100 cc). This result is the observational data of week 10 after planting, in which all variables show the highest result with 100 cc/l/water treatment per plant.

The plants' height growth (upright) with a value (113.94 cm) and a number of leaves up to (19.28 sheets) show that the plants' optimal vegetative growth ensures good generative growth. This is reflected in the flower formation (17.28 flowers formed). According to the observation of flower formation to fruit, only a few flowers fail to shift to fruits. The fruits formed have their shape elongated (23.65 cm) with a little diameter (4 cm). This cucumber size has an economic advantage since harvest time may be regulated when the fruits are young for direct consumption (fresh vegetables) and late harvested fruits may be sold for processed vegetables.

Table 4. Data resulted from linear regression analysis on cucumber plant's characteristics observation variables

Observation variables	Yield Estimation Equation	R^2 Value
Plant's Height (upright)	$Y= 8.811 \chi + 69.38$	0.82
Number of Leaves (mature)	$Y= 1.512 \chi + 11.22$	0.95
Number of Harvest Fruits	$Y= 2.495 \chi + 5.55$	0.95
Harvest Fruits' Diameter	$Y= 0.656 \chi + 0.66$	0.94
Harvest Fruits' Length	$Y= 0.769 \chi + 19.86$	0.98

The descriptions in Table 1, 2, and 3 data show acid-reacting soil types like Ultisol with poor chemical, physical and biological properties (Nurida *et al.*, 2008; Sarhan, 2011). It is appropriate to use brown seaweed extract to ameliorate Ultisol soil since it has NPK content to supply macronutrients and C-organic content and neutral pH 6.8, appropriate to ameliorate soil's physical and biological properties. This is reflected in the cucumber's good growth response and crop yield with good, flawless fruits, indicating that they have sufficient nutrients.

Brown seaweed (*Sargassum polycystum* L.) may be potentially developed as to substrate to produce liquid fertilizer. This is reflected from the regression data (Table 4) presented in the form of equation ($\hat{Y}$) and (R^2) value, that the application, up to 100 cc (S4), remains showing linearity, which means that it may be applied with brown seaweed extract dosage higher than (100 cc) to enhance crop yield. It has good accuracy with ((R^2 value = 0.82 to 0.98), showing that brown seaweed may be potentially cultivated on a large scale to ensure the raw material for commercial liquid fertilizer making.

IV. Conclusion

Based on the analysis results of the research data, it is concluded that dry acid soil like Ultisol remains has potential, since although lacks of fertility, this soil may be engineered with appropriate biomaterial to supply soil nutrients and ameliorant. According to the data, with N-total (2.02%), P_2O_5-total (745 ppm), K_2O-total (708 ppm) and C-organic (19.8%) contents and pH H_2O (6.8) of brown seaweed's tissue (*Sargassum polycystin* L.), it may be applied to dry acid soil. The cucumber crop's highest yield (harvest fruits), 10 pieces, is achieved with 100 cc/l water application per 2 plants.

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