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The effects of seaweed fertilizer on the growth and productivity of upland rice, maize and oil palm grown in green house

Pengaruh pupuk rumput laut terhadap pertumbuhan dan produktivitas padi gogo, jagung dan kelapa sawit di rumah kaca

Djoko SANTOSO[1*)], Tetty CHAIDAMSARI[1)], SYAFARUDDIN[2)] & Dedi Soleh EFFENDI[3)]

[1]Indonesian Biotechnology Research Institute for Estate Crops. Jl Taman Kencana No.1, Bogor 16151, Indonesia
[2] Indonesian Spice and Industrial Crops Research Institute. Jl. Tentara Pelajar No. 3, Bogor 16111, Indonesia
[3] Indonesian Center for Estate Crops Research and Development. Jl Tentara Pelajar No. 1, Bogor 16111, Indonesia

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Abstrak

Sebagai negara kepulauan di daerah tropis, Indonesia kaya akan sumberdaya alam untuk swasembada pangan. Berjuta-juta hektar lahan di Indonesia ditanami tanaman perkebunan, tanaman tahunan yang memiliki masa juvenil yang relatif lama, terutama tanaman kelapa sawit dan karet. Sementara itu, upaya untuk meningkatkan produksi pangan terkendala oleh terbatasnya lahan subur. Penelitian yang mengeksplorasi bioregulator alami mampu meningkatkan produktivitas tanaman, menemukan bahwa Sargasum *sp., rumput laut tipe liar yang di sepanjang pantai beberapa wilayah Indonesia, menunjukkan kemampuannya meningkatkan pertumbuhan dan produktivitas tanaman seperti padi, jagung, tomat dan pertumbuhan kelapa sawit tanpa penambahan pupuk kimia. Percobaan pada padi gogo varietas Batutegi yang ditanam di rumah kaca, menunjukkan bahwa bioregulator alami tersebut meningkatkan produktivitasnya 50% lebih tinggi daripada kontrolnya. Percobaan menggunakan jagung var. Arjuna, tanaman yang telah diperlakukan dengan bioregulator tersebut memproduksi dua hingga tiga tongkol, sementara pada tanaman kontrol hanya satu tongkol. Percobaan pada tanaman kelapa sawit di rumahkaca memperlihatkan bahwa bioregulator tersebut menginduksi pertumbuhan vegetatifnya secara signifikan, lebih baik daripada kontrol dengan atau tanpa pupuk kimia.* Intercropping *tanaman kelapa sawit TBM dengan tanaman pangan seperti padi gogo atau jagung, diharapkan lebih menguntungkan bagi usaha perkebunan.*

[Kata kunci: Sargasum *sp., padi gogo, jagung, kelapa sawit*]

Abstract

Being a tropical archipelago, Indonesia is rich with natural resources enabling more production for food. Millions hectares of Indonesian lands is now planted with estate crops, perennial crops with relatively lengthen juvenile phase mainly oil palm and rubber. Meanwhile, attempts to increase national food production have been limited by availability of fertile lands. Our research exploring natural bioregulator capable of improving crop productivity, found that *Sargasum* sp., a wild sea weed grown mostly along the coast line in Indonesia, indicated its ability to improve the growth and productivity of crops like rice, maize, tomato and oil palm even though with no chemical fertilizers added. The experiment on upland rice of local variety Batutegi planted in greenhouse, demonstrated the natural bioregulator has increased the rice productivity by at least 50% over the control. The experiment using maize var. Arjuna, the bioregulator treated plants has made two to three corncobs instead of only one corncob on the control plants. The experiment on the oil palm grown in the nursery showed that the bioregulator has significantly induced vegetative growth better than the control with or without chemical fertilizers. Intercropping the food crops, rice or maize in the juvenile phase of the oil palm plantations, should be beneficial to the productivity of the plantation.

[Keywords: *Sargasum* sp., upland rice, maize, oil palm]

Introduction

To secure food availability with cheap price requires an improved production of the corresponding food. One of the limiting factors in improving the production the staple foods such as rice and corn has been the availability of fertile lands for the food crops to grow. Being located in tropical region, Indonesia has natural resources, including fertile lands, enabling to be world producer for foods. Some of the fertile lands in the country have been planted with estate crops such as oil palm, rubber and cacao trees, which are perennial crops with lengthen juvenile phase, three to five years. The area of oil palm plantation in Indonesia is almost 8 millions hectares (Ditjenbun, 2010). During the juvenile periods, the canopies of the neighboring trees have not yet overlapped each others so that enable planting annual crops like rice and maize in between.

This research aimed to study the effect of seaweed organic fertilizer on some agronomical characters of local varieties of upland rice (*gogo*) of *Batutegi*, *Arjuna* maize, and *Tenera* hybrid of oil palm. The experiments for each crop were conducted in green house for one harvest cycle except for the oil palm, which has been performed for a year period of nursery. The parameters observed were the vegetative growths of the rice, maize and oil palm, and the reproductive developments for the rice and maize.

*) Penulis korespondensi:djsantoso@yahoo.com

The chlorophyll content was examined in the leaves of oil palm as the greenish color intensity visually distinctive among the treatments.

The result of the experiments demonstrated that the seaweeds organic fertilizer formulae were significantly improved the vegetative growths of the three tested crops. As a consequence, this improvement positively affected the reproductive development of the rice and the maize as well, leading to the increase of the seeds or fruits productivity of the two crops. Because of lengthen juvenile phase, an improved reproductive growth would predictably increase productivity of oil palm later during the productive phase.

Materials and Methods

The *Batutegi* gogo rice and *Arjuna* corn seeds were kindly provided by Dr. Asadi from Indonesian Center for Agricultural Biotechnology and Genetic Resources Research and Development (ICABIOGRAD) in Bogor, Indonesia. *Tenera* hybrid of oil palm seedlings were purchased from Indonesian Oil Palm Research Institute (IOPRI) in Medan, Indonesia. Chemicals of technical and pure grades were obtained from local suppliers.

Preparation of seaweeds organic fertilizer

Seaweeds of *Sargasum* sp. freshly collected from Gunung Kidul Yogyakarta, were rinsed two to three times with clean water to remove salt. After drained to remove the excess water, the cleaned seaweeds were sundried for 2 to 3 days or until the remaining water content was 5 to10 %. The dried seaweeds were stored until the next usages or ground with powdering machine just before the following uses.

Planting the seeds and treatments

Top soil media were mixed with 2 or 5 % (v/v) of freshly seaweed powder. After contained in 25 liter polybags, the media were used to germinate and grow two good seedlings of rice, one good seedling of corn and one good seedling of oil palm. To keep the humidity under control, the planted media were watered once a day in the early morning or the afternoon. After 1 to 2 weeks, the growing seedling of rice or maize was selected for the best one to grow further. During the growing cycle the pertinent agronomical traits were recorded. Two types of control treatments were seedlings grown on top soil media with or without conventional fertilizers NPK or compost. Additional exogenous hormonal formulations for plant were applied periodically through foliar sprays of the tested plants.

Determination of the chlorophyll contents

Analysis of chlorophyll content in the leaves was determined using the Arnon method as described by Parman & Harnina (2008). The contents of chlorophyll-a were calculated from the OD at 665 nm multiply by 5.76, and chlorophyll-b equals to 25.8 times (the OD 649 – 7.7 OD 665).

Results and Discussion

There are several types of seaweeds available in local markets. Table 1 lists five of them that can be purchased from a local supplier residing in southern coastal of Java island. Based on the high availability and the low price, *Sargasum* sp. can most likely be used as organic fertilizer in plantation. The only limitation is that it is rarely cultivated so that seasonally dependence. *Sargasum* sp. of the powder form was then utilized in the following experiments.

The first experiment was to examine the effects of the seaweed organic fertilizer in a form of relatively fresh powder, to the vegetative growth and reproductive development of maize of *Arjuna* variety. The results are presented in Table 2. With (Fisca BiH, Fisca BiF1 and Fisca BiF2) or without (Fisca BiM) additional plant hormone, both their vegetative growth and the reproductive development of the tested maize plants were better than those of the control plants. Additional plant hormones were able to induce more corncobs even though they did not always reflect to end productivity or the total seed weight.

These results are in line with the research reporting that seaweed was mostly contained several types of plant hormones (Eswaran *at al*., 2005). This might be the reason why *Sargasum* sp. with or without additional exogenous plant hormone did not differ significantly on the effect to the growth and development of maize compared to those of the control plants. Similar responses were also found in the following experiment on non-arid land of upland rice type, as shown the results below (Figure 1). The application of the seaweed organic fertilizer was able to improve the vegetative growth of the rice by regenerating more shoots of varying stages in a ratoon. These shoots enabling the rice crops were harvested at least twice in one planting. In control plants however, the harvest is only one time. Figure 1 indicates that after one harvest the control rice ratoon in the polybags did not regenerated any shoots. In treated rice however the negative rice ratoon made more shoots. Later, these newly formed shoots would grow and produced good rice seeds.

Table 1. The relative availability and price of some seaweeds at local supplier.
Tabel 1. Tipe dan harga seaweed *yang tersedia di pasar lokal*

Type *Tipe*	Wild/Cultivated *Liar/Dibudidayakan*	Production, ton/year *Produksi, ton/th*	Price, Rp/kg *Harga, Rp/kg*
Gelidium	wild	120	11.000
Pitata/Bludru	wild	10	22.000
Sargasum	wild	150	5.000
Gracilaria	wild	50	14.000
Supinosum	cultivated	60	35.000

Table 2. The effects of seaweed organic fertilizer formulae on the growth and productivity of maize. The numbers are the averages of 5 to 7 data
Tabel 2. Pengaruh formula pupuk organik rumput laut terhadap pertumbuhan dan produksi Jagung. Data adalah rata-rata dari 5- 7 data pengamatan.

Formula treatments *Perlakuan*	Plant height *Tinggi tanaman* (cm)	Trunk diameter *Diameter batang* (cm)	Leaf number *Jumlah daun*	Corncob number *Jumlah tongkol*	Corncob weight *Berat tongkol* (g)		Total seed weight *Berat biji total* (g)
					Primary *Pertama*	Second *Kedua*	
Negative Control	85±27	1.3±0.2	8±1	1.0±0.0	34±8	0	2.9±2.0
NPK Control	102±18	1.3±0.1	8±1	1.0±0.0	50±32	0	4.4±6.4
Fisca BiM	117±14	1.7±0.3	12±1	1.0±0.0	153±25	0	14.9±1.7
Fisca BiH	128±17	1.8±0.1	12±1	3.5±0.7	179±6	37±25	17.4±3.0
Fisca BiF1	143±16	1.7±0.1	13±3	2.0±0.3	155±10	7±3	18.2±0.2
Fisca BiF2	96±13	2.0±0.1	13±1	2.5±0.7	163±39	56±44	13.9±0.1

Reproductive development leading to an improved productivity of seed crops is mostly started at flower initiation. The role of plant hormones in flowering initiation has been discussed as one of the pathways of flower initiation (Sung *et al.*, 2003; Corbester & Coupland, 2006) and practical interest in horticultural trees (Wilkie *et al.*, 2008). Flowering-inducing hormone is common to all flowering plants. This florigen functions as a general systemic regulator of growth (Shalit *et al.*, 2009). In rice research, the mechanism by which hormone florigen induces flowering initiation is mediated by an intracellular receptor of 14-3-3 proteins (14-3-3 OsFD1). The interaction occurs in cytoplasm of shoot apical cell where flower buds produces. A complex of florigen and its receptor initiates transcription that triggers flower bud formation (Taoka *et al.*, 2011).

The number and quality of rice seeds produced in this experiment is summarized in Table 3. In control ratoons, growing shoots was only once, but the treated ratoons, the shoots were regenerated twice. In the rice plants treated with chemical fertilizer NPK, during the second cycle the most shoots were regenerated. However, the quality of the seeds produced was inferior. In the rice treated with *Sargasum* sp., the number of shoots regenerated in second cycle was higher than those in the first cycle but lower than either those in the first cycle or the second cycle of NPK treatment. Nevertheless the quality of the seeds produced in *Sargasum* sp. treatment is better than that in NPK treatment as indicated by the weight of 100 seeds, which were 1.74 g versus empty. The productivity of the second harvest cycle is around (2.5 x 1.74) / (1.55 x 1.41) = 199%. If the cycle 1 needs 110 days, because started at the mid of the first cycle, the second cycle start needs only 55 days after the end of the first cycle. With regard to the time, the improved productivity from the use of *Sargasum* sp. organic fertilizer should be around 199% times 110d/165d, equals to 133%.

Improving national food security through intercropping of the plantations with food crops using organic fertilizer of seaweeds, needs to examine the effects of the primary input, the fertilizer, to the primary crops. Plantation in Indonesia is largely composed of oil palm, which is now covered an area of around 8 millions ha (Ditjenbun, 2010). The result of the experiment to examine the effect of *Sargasum* on the growth of juvenile oil palm is shown Table 4. Compared to the control plants, the plants grown in the

Figure 1. The growth of upland rice after the first harvest cycle. (Note the growing ratoons at *Sargasum* sp. treated plants (right) as compared to negative control (left))

Gambar 1. Pertumbuhan padi gogo setelah siklus panen pertama. (Ratoon tumbuh dengan baik pada perlakuan Sargasum *sp. (kanan) dibanding dengan kontrol negatif (kiri)).*

Table 3. Productivity upland rice var Batutegi grown in polybags in the green house. The numbers are the averages of 5 to 7 data.

Tabel 3. Produktivitas padi gogo var. Batutegi yang ditumbuhkan dalam polibag di rumah kaca. Data adalah rata-rata dari 5-7 data pengamatan.

	Growing shoots *Jumlah anakan*		Weight 100 seeds (g) *Berat 100 biji (g)*	
	Cycle 1 *Siklus 1*	Cycle 2 *Siklus 2*	Cycle 1 *Siklus 1*	Cycle 2 *Siklus 2*
Control *Kontrol*	1.47 ± 0.35	0.0	1.23 ± 0.21	Not grown
NPK treatment *Perlakuan NPK*	5.04 ± 2.21	5.75 ± 2.44	0.31 ± 0.10	Empty
Sargasum reatment *Perlakuan* Sargasum	1.55 ± 0.36	2.50 ± 0.50	1.41 ± 0.12	1.74 ± 0.57

Table 4. The growth of oil palm on the polybag in the green house. The numbers are the averages of 5 to 7 data.

Tabel 4. Pertumbuhan sawit dalam polibag di rumah kaca. Data adalah rata-rata dari 5-7 data pengamatan.

	Plant *Tanaman*	Control with none *Pembanding negatif*	Control with compost *Pembanding dengan kompos*	Control with NPK *Pembanding dengan NPK*	The best of tests *Perlakuan terbaik*
Height *Tinggi*	23 wap	32.4±2.4	32.8±2.2	32.6±2.3	35.6±3.9
	30 wap	39.8±1.6	36.8±3.7	45.8±4.8	49.2±5.3
Leaf number *Jumlah daun*	23 wap	6.8±0.5	7.2±0.5	7.8±0.5	7.4±0.6
	30 wap	8.4±0.6	8.4±0.6	9.6±1.1	10.0±0.7

Figure 2. The growth of oil palm at 23 weeks after planting in nursery. From left to right is control media, added compost, NPK, and seaweed (*Sargasum* sp.) organic fertilizer respectively.

Gambar 2. Pertumbuhan kelapa sawit pada umur 23 minggu setelah tanam di pembibitan. Dari kiri ke kanan adalah pembanding negatif, pembanding dengan kompos, pembanding dengan NPK, dan perlakuan dengan pupuk organik Sargasum *sp.*

soil containing 2% (v/v) of *Sargasum* powder had the best vegetative growth. Even they were better than those fertilized with NPK. It was averaging around 7.4 % taller than control with NPK and 23.6 % taller than control with only top soil. They have made more leaves with better appearance (Figure 2). Figure 2 shows the appearance of oil palm growing in polybags with top soil media supplemented with various types of fertilizer. In addition to taller, the oil palm seedling growing with 2% seaweeds organic fertilizer has leaves greener than the control with none and equally green as control with NPK. In most cases, the green color of leaves may represent the functionality of the leaves, which are performing photosynthesis. Photosynthesis in leaf molecularly depends on the presence of chlorophyll. To relate the greenish appearance with the chlorophyll content, analyses to determine the chlorophyll content were conducted. The results indicates that there is positive correlation between the intensity of the green color with both chlorophyll-a and chlorophyll-b contents in the leaves (data not shown). In addition sewed fertilizer has become a preferred organic substance to add nutrion to plant. Seaweed absorbs the vitamin, minerals and enzymes present in the sea and retains more than 70 of the vital nutrients (Carpenter, 2011), which also useful to plants.

To estimate how much rice may be produced from intercropping of oil palm plantation with upland rice some assumption are made. According to Ditjenbun (2010) the total area of oil palm plantation in Indonesia is almost 8 millions ha (7,824,623 ha). The first assumption is that as much as 25% of those areas are juvenile oil palm which can be used for intercropping with upland rice. The productivity of upland rice planted as intercrops between oil palm is assumed 25% than that in open field, which was reported as much as 5.9 ton per hectare (Humas, 2011), therefore total rice that might be produced through the intercropping would be around 11.5 millions ton per year. This is from 0.25 x 7824623 x 0.25 x 5.9 x 2 = 11.5 million ton per year. Assuming that the use of *Sargasum* sp. organic fertilizer is able to improve productivity of the upland rice by 133%, the total rice production by this technology in the oil palm plantation theoretically could be 11.5 times 233% = 26.8 million ton per annum. With this number, almost 50% of national need for rice would be satisfied. The national need for the rice was estimated equal to rice seed (*Gabah*) 54.905 million ton annually (Anonym, 2010). An additional advantage is that the application of the seaweed fertilizer was also able to improve the vegetative growth of juvenile oil palm. A better growth during juvenile phase is expected to improve productivity during the next phase (Santoso & Widiastuti, 2011). The productivity of oil palm in Indonesian plantation is significantly lower than its potency, around 20 ton FFBOP (fresh fruit bunches of oil palm) per ha per year (Suryana *et al.*, 2007) compared to 40 ton FFBOP per ha per year of its potency. Experimental result on these mono-cotyledonous species is in agreement with reports in some horticultural crops such as onion (*Allium cepa* L.), garlic (*Allium sativum* L.), pepper (*Capsicum* L.) and sweet potato (*Ipomoea batatas* (L.) Lamk) (Anonym, 2011) that Sargasum can be used as fertilizer.

Conclusion

Application of *Sargasum* sp. organic fertilizer with or without additional exogenous plant hormones was able to improve significantly the vegetative growth of *Batutegi* upland rice, *Arjuna* maize and *Tenera* hybrid of oil palm in green house. This sequentially improves the reproductive development of the annual food crops by around twice higher. Theoretically, intercropping of the juvenile oil palm plantations with the food crop of upland rice using *Sargasum* sp. organic fertilizer may significantly improve national food security.

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