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Research Article
Effect of Indonesian Macroalgae Based Solid and Liquid Fertilizers on the Growth and Yield of Rice (*Oryza sativa*)

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Abstract

Background and Objective: In Indonesia, most of the population relies on rice as their main staple food; however, the production of rice is dependent on inorganic fertilizers which not only increase cost production but also decrease soil fertility and pollutes the environment. Therefore, the development of organic fertilizers derived from natural resources which are more affordable with high bioavailability has recently become an important study. This study aimed to evaluate the effects of solid and liquid macroalgae extract on growth and yield of rice plants. **Materials and Methods:** The treatments consist of solid, liquid extract of brown macroalgae, such as *Sargasum crassifolium*, *Sargasum cristaefolium*, *Sargasum aquifolium* and *Turbinaria murayana*, combined solid form of all algae species and combined liquid form of all algae species. Treatments were conducted in 8 weeks, followed by measurements of vegetative growth and yield of rice plants. **Results:** The results show that solid and liquid extracts have different efficacy on growth and yield of rice plants. Application of macroalgae solid fertilizer increased vegetative growth; such as number of leaves and tillers in rice plants compared to liquid fertilizer treatments. Interestingly, macroalgae liquid fertilizer proved to be more effective in promoting yield based on shoot/root (S/R) ratio. However, 1000 seed weight of rice plants were not affected by fertilizer treatments. **Conclusion:** Nevertheless, current study provides effectiveness of macroalgae liquid fertilizer compared to solid fertilizers. Further evaluation of macroalgae fertilizer mechanism in promoting growth and yield of rice plants would be necessary for utilization in various agricultural industries.

Key words: Solid extract, liquid extract, macroalgae liquid fertilizer, rice plants, Indonesia, liquid fertilizer treatments

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Asian rice (*Oryza sativa*) is the most important staple food crop in most of the Asian countries; such as Indonesia[1]. Rice has immense nutritional value with high amounts of starch content, proteins, carbohydrate with oil and vitamins occurring in the tissues of the grain[2]. Due to the importance of rice in Indonesia, the demand for rice increases from year to year. Statistics Indonesia (BPS) reported that rice production has increased from 71.3-75.4 million t from year[3] 2013-2015. However, the increase of rice production fails to meet the national food needs.

A solution to core constraints regarding increasing demands in rice consumption is to increase yield production in per hectare of rice crop. Application of inorganic fertilizers to boost production has become a main option to increase yield production of plants[4,5]. However, inorganic fertilizers have been reported to provide low efficiency for crop production. Instead, the excessive use of inorganic fertilizers increases production cost and induces environment pollution[6]. Hence, there arises importance for development of organic fertilizers based on natural resources with high bioavailability to reduce production cost and provide economical sustainability for farmers.

Marine macroalgae are considered as excellent source of bioactive compounds that has broad range of biological activites[7-9]. Macroalgae extracts also have been used in agricultural trends as soil conditioners and fertilizers to enhance crop productivity. Aqueous extract of *Sargassum wightii* when applied as foliar spray on *Zizyphus mauritiana* showed an increased yield and quality of fruits[10]. Brown macroalgae *Padina* induced maximum seedling growth at lower concentrations in *C. cajan*[11]. Some reports also demonstrated that *Hypnea musciformis*, *Spatoglossum asperum*. *Stoechospermum marginatum* and *Sargassum* induces the growth of plants such as green chilies, turnips and pineapple[12,13]. In addition, our previous study reported 15 macroalgae species which could stimulate the germination of watermelon and sesame seeds[14].

Liquid extracts obtained from seaweeds have previously gained importance as foliar sprays for several plants since long ago in several developed countries such as UK, Japan, New Zealand and Singapore[15]. However, there remains limited information of Indonesian macroalgae potential as biostimulant and organic fertilizer. This study aimed to evaluate the efficiency of macroalgae *Sargassum cristaefolium*, *Sargassum crassifolium*, *Sargassum aquifolium* and *Turbinaria murayana* based solid and liquid fertilizer in yield production of rice. Results from this study would provide insights in further development and utilization of macroalgae derived organic fertilizers for sustainable rice production.

MATERIALS AND METHODS

Collection of macroalgae: The macroalgae used in the present study were *Sargassum cristaefolium*, *Sargassum crassifolium*, *Sargassum aquifolium* and *Turbinaria murayana.* They were collected from the Batu Layar coastal area of Lombok West Nusa Tenggara, Indonesia (8°30'57"S, 116°07'40"E) during March, 2018. The algae species were hand-picked and washed thoroughly with seawater to remove all the unwanted impurities, adhering sand particles and epiphytes. Morphologically distinct thallus of algae were placed separately in new polythene bags and were kept in an ice box containing slush ice and transported to the laboratory. Samples were washed thoroughly using tap water to remove the salt on the surface of the sample. The water was drained off and the algae were spread on blotting paper to remove excess water.

Preparation of macroalgae solid and liquid fertilizers: One kilogram of macroalgae was cut into small pieces and extracted separately with 1:1 ethanol solvent. Followed by three times maceration and followed by further evaporation. The remaining filtrates were taken as 100% concentration of seaweed extract and from this, concentration of 5% was prepared using distilled water[16]. Liquid fertilizers were applied at 5% concentration during vegetative growth. For solid fertilizers, extract residues of macroalgae were used at the amount of 25 g per trial plot.

Preparation of seedlings and soil: Growth medium used in this study was a mixture of soil and tested fertilizers with 3:1 ratio in trial plots (8 kg soil mixture). Rice used in this study was seeded for 14 days before transferred to trial plots. Prior to rice planting in trial plots, rice seedlings were soaked in water for 24 h. Every trial plots were planted with three seedlings in 2.5-3.0 cm depth.

Experimental design: A complete randomized block experimental design was used with three experimental plot units (replications) per treatment group. Each experimental plot unit had a surface area. There were 11 different treatment groups, one control which received chicken dung fertilizer treatment (P0), solid fertilizer of macroalgae extracts

of *Sargassum cristaefolium* (P1), *Sargassum crassifolium* (P2), *Sargassum aquifolium* (P3), *Turbinaria murayana* (P4), solid mixture of all macroalgae extracts (P5), solid fertilizer of macroalgae extracts of *Sargassum cristaefolium* (L1), *Sargassum crassifolium* (L2), *Sargassum aquifolium* (L3), *Turbinaria murayana* (L4), liquid mixture of all macroalgae extracts (L5) . All treatments were done in 8 weeks before measurement of vegetative growth and yield was conducted.

Plant growth and performance measurements: Measurements were done on 6 randomly selected plants per experimental unit (6 plants per treatment). Plant height, leaves count, seedlings count, shoot dry weight, root dry weight, weight of 1000 seeds and S/R ratio.

Statistical analysis: Analysis of variance was used to detect significant differences of effects between treatments. Treatments were compared using Tukey's test ($p<0.05$). The analyses were performed using the Statistica Software, version 10 (Statsoft Inc. Tulsa, Oakland, USA).

RESULTS

Evaluation of vegetative growth attributes of rice crop revealed that application of different macroalgae species in different fertilizer forms results in adverse effects. Overall, the solid fertilizer treatments demonstrated positive effects in promoting vegetative growth. Whereas, liquid fertilizers show more affect in promoting yield content of rice plants.

Plant height: Macroalgae solid treatments show positive effects in rice crop plant height (Fig. 1). Overall, there was no difference in plant height among the fertilizer treatments. However, macroalgae extract *S. crassfolium* solid fertilizer induced significant effect in rice crop plant height compared to other macroalgae fertilizer treatments and control.

Number of leaves: Significant variation was found in the number of rice crop leaves grown in various macroalgae species extract solid and liquid fertilizer (Fig. 2). Rice plants treated with solid macroalgae of *S. crassifolium*, *S. cristaefolium* and *S. aquifolium* resulted in approximately equal number of leaves compared to control. However, treatment with other solid fertilizer macroalgae *T. murayana* and mix extracts resulted in lower number of leaves compared to control.

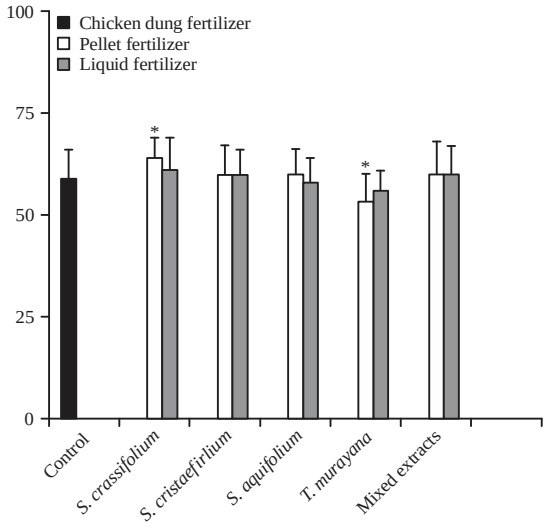

Fig. 1: Effects of different solid and liquid macroalgae extracts in rice crops plant height in 8 weeks cultivation
Values followed by different letters in columns are statistically different ($p<0.05$) and highly statistically different ($p<0.01$)

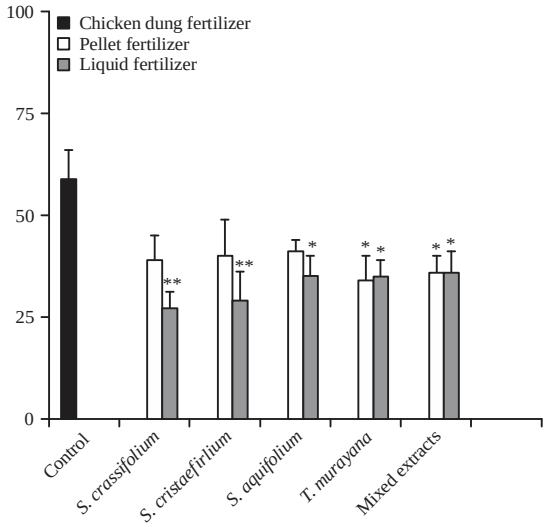

Fig. 2: Effects of different solid and liquid macroalgae extracts in rice crops number of leaves in 8 weeks cultivation
Values followed by different letters in columns are statistically different ($p<0.05$) and highly statistically different ($p<0.01$)

Number of tillers: Rice plants treated with solid fertilizer macroalgae *S. crassifolium*, *S. cristaefolium* and *S. aquifolium* resulted in higher number of tillers compared to control (Fig. 3). However, solid fertilizer *T. murayana* and mixed extracts seemed to have little effect in promoting leaves number. In addition, liquid fertilizer of all macroalgae extracts demonstrated significantly lower effect in number of tillers compared to control.

Table 1: Effects of different solid and liquid macroalgae extracts in rice crops yield dry weight content in 8 weeks cultivation

	Pellet fertilizer			Liquid fertilizer		
Perlakuan	Shoot dry weight (g)	Root dry weight (g)	S/R ratio	Shoot dry weight (g)	Root dry weight (g)	S/R ratio
Control	29.78	8.20	3.63	29.78	8.20	3.63
S. crasstfolium	30.08	16.38*	1.84	28.85	6.58	4.39
S. cristaefolium	32.43	8.48	3.83	28.90	6.98	4.14
S. aquifolium	30.20	7.70	3.92	30.40	8.85	3.44
T. murayana	29.23	8.73	3.35	30.73	7.53	4.08
Mixed extracts	27.55	10.28	2.68	29.85	10.58	2.82

Values followed by different letters in columns are statistically different ($p<0.05$) and highly statistically different ($p<0.01$)

Table 2: Effects of different solid and liquid macroalgae extracts in rice crops yield 1000 seed dry weight content in 8 weeks cultivation

	1000 seed weight (g)	
Treatments	Pellet fertilizer	Liquid fertilizer
Control	29.63	30.17
S. crassifolium	30.05	28.85
S. cristaefirlium	32.35	26.40
S. aquifolium	31.62	30.40
T. murayana	29.08	30.73
Mixed extracts	33.00	30.17

Highly statistically different at $p<0.01$

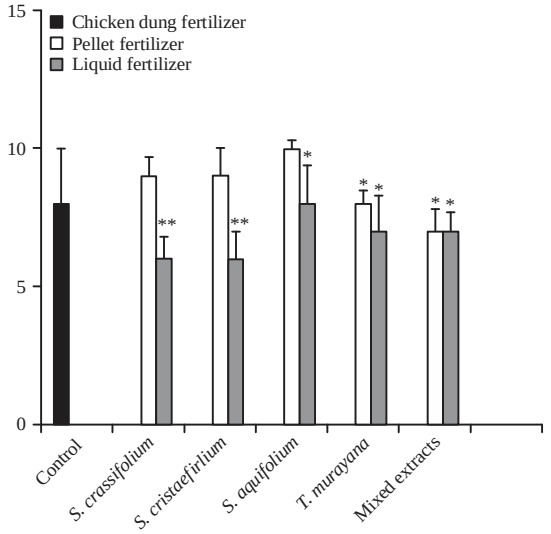

Fig. 3: Effects of different solid and liquid macroalgae extracts in rice crops number of tillers in 8 weeks cultivation

Values followed by different letters in columns are statistically different ($p<0.05$) and highly statistically different ($p<0.01$)

Dry weight: Regard the dry weight matter contents, macroalgae liquid fertilizers proved to be more effective in promoting yield content based on shoot/root (S/R) ratio (Table 1). Particularly S/R ratio of plants treated with liquid macroalgae fertilizer *S. crassifolium* (4.39), *S. cristaefolium* (4.14) and *Turbinaria murayana* (4.08) were higher than solid macroalgae fertilizer respectively (1.84, 3.83 and 3.35).

1000 seed weight: Measurement of 1000 seed weight is an important yield contributing character. The 1000 seed weight of rice crop overall did not vary significantly with fertilizer treatments (Table 2).

DISCUSSION

Indonesia ranks as the third country in the world in population number and the staple food of its people is rice[17]. However, Indonesia national rice production could not meet the whole nation demands. It is expected that there will be great deficiency of rice demands in the future[18]. Inorganic fertilizers have become a solution to promote crop production. However, it has been reported to provide low efficiency for crop yield and growth. Hence, a solution to increase the production of rice crop is needed to be developed adequately. To meet this goal, development of natural resources based organic fertilizers is necessary[19,20]. The present study highlights the efficiency of macroalgae fertilizer forms between solid and liquid fertilizer form of selected Indonesian wild-type macroalgae *Sargassum cristaefolium*, *Sargassum crassifolium*, *Sargassum aquifolium* and *Turbinaria murayana* effects in growth and yield of rice plants.

Macroalgae show great promise as a source of bioactive compounds potential for promoting growth and yield in plants[21-24]. Overall, in the present investigation rice plants treated with solid fertilizer of brown macroalgae *S. crassifolium*, *S. cristaefolium* and *S. aquifolium* demonstrated most promising efficacy in increase of vegetative growth in rice plants. Macroalgae *Sargassum* based fertilizers used within different crop production systems have resulted in increased crop productivity[25]. Furthermore, in parts of China, *Sargassum* spp. are considered as a low cost fertilizer in sweet potato production[26]. Macroalgae *Sargassum* based fertilizers used within different crop production systems have resulted in increased crop productivity. In addition, previous reports have evidenced macroalgae potential as organic fertilizer. A literature reported that *Chaetomorpha antennina* and *Rosenvingea intricate* on the growth of *Abelmoschus esculentus* and *Raphanus sativus*[27]. Brown macroalgae *Stoechosperum marginatum*

and *Sargassum* demonstrated increased growth effects on green chillies, turnips and pineapples[28].

In the present study the rice plants treated by solid fertilizer of macroalgae extracts exhibited promising profiles of increased vegetative growth characteristics compared to liquid fertilizers. Solid fertilizer of macroalgae *S. crassifolium* and *S. aquifolium* induced significantly plant height and number of tillers. Whereas, liquid macroalgae fertilizers proven to be more affective in promoting yield content in rice plants. Liquid macroalgae have been reported to be more affective in providing macro and micronutrients which are essential for promoting yield contents in plants[29]. However, evaluation of macro and micronutrients contained in treated rice plants with macroalgae fertilizers is needed to confirm this result. Furthermore, macroalgae *S. crassifolium* demonstrated most promising affects in both forms solid and liquid. Treatment with liquid macroalgae *S. crassifolium* fertilizer significantly increased yield content in S/R ratio (4.39) compared its solid fertilizer form (1.84). Macroalgae *S. crassifolium* fertilizers have been reported as source of secondary nutrients such as Mg; hence, it helps in root growth[30,31].

CONCLUSION

Solid fertilizers are still believed to provide higher efficacy in promoting crop growth and yield compared to liquid fertilizers. As certain solid fertilizers show significant effect in promoting vegetative growth. However, liquid organic fertilizers offer sustainable agriculture as the special compounds in such liquid organic fertilizers, such as chitin, humic and fulvic acids and other biopolymers, could be biostimulants to plants if used in the right concentrations. Nevertheless, macroalgae *S. crassifolium* shown most promising effects in promoting yield content in rice plants. Further evaluation of macroalgae *S. crassfiolium* based fertilizer would be necessary for obtaining maximum effect in growth and yield of plants.

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