The potential of seaweed waste (gracilaria sp. and eucheuma cottonii) as a medium density fiberboard (mdf)-based pot material for better water use efficiency in tomato plants

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The potential of seaweed waste (*gracilaria* sp. and *eucheuma cottonii*) as a medium density fiberboard (mdf)-based pot material for better water use efficiency in tomato plants

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Abstract. The demand for seaweed of the *Gracilaria* sp. and *Eucheuma cottonii* varieties is getting higher. The increasing seaweed culture can create a waste effect, as among other things, there are variations in quality that can cause rejection in the industry, as the harvest period is not universal, and neither is cleanliness in handling. One of the utilizations of seaweed waste that has a lignocellulose content is that it is one of the basic ingredients of Medium Density Fiberboard (MDF). Polybags as a growth medium can still cause the roots of the plants to grow in a circle of plastic. Polybag plastic is not easily degraded, so that there has been an increase in plastic waste dumping. The aim of this research is to determine the water use efficiency and the tomato plant growth rate using seaweed waste (*Gracilaria* sp. and *Eucheuma cottonii*) as an MDF pot material polybag substitute. This research used a completely randomized design with four treatments and five repetitions. The results of this research showed that the use of seaweed waste as a MDF-based pot material polybag substitute had a significant effect on the different water use efficiencies.

1. Introduction

Indonesia is a country with abundant natural resources, one of which is seaweed. Seaweed is widely used for industrial purposes such as in food and beverages, beauty cosmetics, ink, paper and medicine [1]. *Gracilaria* sp. is a seaweed that is cultivated in the mouth of rivers or in ponds [2] and *Kappaphcyus alvarezii*, commonly called *Eucheuma cottonii*, is a kind of red algae that has a wide range of potential and has been cultivated since 1980 [3]. The demand for seaweed commodities is encouraging Indonesia to increase their level of seaweed processing and cultivation, resulting in a lot of seaweed waste that is usually only left to accumulate in landfill sites [4].

However, due to the high demand for *Eucheuma cottonii*, the increase in seaweed cultivation has caused increased waste. Variations in quality cause industrial rejection, uneven harvest time, varied hygienic handling and drying processes and packaged waste being scattered at the place of processing [5]. There needs to be a better way to utilize the seaweed waste containing lignocelluloses, such as to make a type of wood panel [6].

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Medium Density Fiberboard (MDF) is made from lignocellulose fibers combined with synthetic resins or other suitable bonds when under both heat and pressure, up to 45 Pa [7]. Making Medium Density Fiberboard (MDF) generally uses wood powder from trees; this triggers its relationship with global environmental issues. Changing the function of Medium Density Fiberboard (MDF) from furniture products into make a pot based on seaweed waste from *Gracilaria* sp. and *Eucheuma cottonii* would replace polybags or temporarily reduce the effect of global environmental issues.

Plant growth still commonly includes polybag use as a growth medium. Polybags have disadvantages, such as the roots of the plants growing in a circle of plastic and polybag plastic not easily degrading in the environment or through the actions of the microorganisms that live in the soil. This results in an increase in the accumulation of plastic waste [8]. The process of plant growth often creates problems such as the use of water for watering plants causing drought; this occurs in the growth phase that greatly affects the crop yield and can cause a decline [9].

Plants that still use polybags include tomato plants. A tomato is a kind of vegetable that has many benefits for health. This is because tomatoes contain vitamin C and vitamin A. They are a very important source of substances that can increase bodily activity. Tomatoes belong to the vegetable group and have a high economic value [10].

Based on the problem above, it is necessary to do research related to the seaweed waste of *Gracilaria* sp. and *Eucheuma cottonii* related to its potential use as the base material and wood powder in Medium Density Fiberboard (MDF) as a substitute for polybags. This should prompt the water volume to be more optimal and efficient, as well as promoting the optimization of seaweed waste and reducing the use of plastic.

2. Research material

2.1. Place and time of research

This research was conducted from December 2016 until January 2017. The construction of the Medium Density Fiberboard (MDF) was conducted at a forging garage in Waru Sidoarjo. The physical and biological characteristic testing was conducted in the Wet Laboratory of the Fisheries and Marine Faculty of Airlangga University.

2.2. Tools and materials

The tools used were a cylindrical iron plate with an upper diameter of 7 cm and a bottom diameter of 6.5 cm. The height was 6 cm for the first printer. The cylindrical iron plate had an upper diameter of 11 cm and a bottom diameter of 9.5 cm with a height of 8 cm in the tool used for printing the polybags. The other tools included lamp ovens, fittings, stirrers, basins, analytical scales and rulers. The base materials used consisted of *Gracilaria* sp. obtained from cultivation farmers in Jabon, Sidoarjo and *Eucheuma cottonii* obtained from seaweed farmers in the Sumenep Madura area. The wood powder was obtained from the remnants of the wooden furniture in the area around Tempurejo and the adhesive material was obtained from building stores in the Surabaya area. The soil and tomato seeds were obtained from a plant shop on Kenjeran Street.

2.3. Procedure of the research preparation

The preparation included the main material collection activities, covering the seaweed waste, wood powder and adhesive additive. The seaweed waste materials made up 100% of the first pot and 50% of seaweed waste and wood powder for the second pot. The range of adhesive content used in the dry process was from 8 to 11% of the dry weight [11]. This experiment consisted of four treatments as follows: P0: plastic polybag, watered with 10 ml twice daily; P1: Pot 1 + Pot 2 with 100% water volume; P2: Pot 1 + Pot 2 with 75% water volume; P3: Pot 1 + Pot 2 with 50% water volume.

The percentage of the water volume in the particleboard based on the pots was 100% as much as 250 ml, 75% as much as 187.5 ml and 50% as much as 125 ml of the volume of both pots. The water requirement of the plant was determined based on the value of the water content [12]. Tests at the tomato planting stage used soil media that had been mixed with organic fertilizer and tomato seeds, soaked for 24 hours before being planted in the soil media. The tomato plant testing was done for 25 days until the plant was ready to be planted in the field.

Before conducting the forging phase, the seaweed was cleaned up. Natural drying was conducted for ± 3 days and an oven was used to decrease the water content. The next stage consisted of grinding the seaweed down to obtain a powder from the seaweed that was filtered using a sieve with a 40 mesh size. The preparation of other materials included wood powder with a 100 mesh size, due to the mixture of materials and synthetic adhesive additives.

2.4. Making of Medium Density Fiberboard (MDF)

The Medium Density Fiberboard (MDF) was created using a dry process, using a hot press. After the raw material was mixed with adhesive, the pressing was done using a hot press at a temperature of 170 °C with a pressure of 45 Pa for 25 minutes [13]. The first particle board was cylindrical with an upper diameter of 7 cm, a height of 6.5 cm and a diameter at the base of 6 cm. For the second particle board pots, they had an upper diameter of 11 cm, a height of 8 cm and a base diameter of 9.5 cm. They were then re-conditioned for 2 days to become high-quality particleboard.

2.5. Parameters of research

In this research study, the main parameters that were observed included biological tests, namely the germination and growth rate of the tomato plants. The growth rate of the tomato plants was determined by measuring the length of the stem, the length and diameter of the leaves, and the root length by using a ruler. The supporting parameters that were measured during the research were temperature, soil pH and soil moisture, all used for testing the results of the research.

2.6. Data analysis

The experimental research results and data analysis of the results were determined using ANOVA (Analysis of Variance), in accordance with the Completely Random Design used which aimed to determine the manufacture of *Medium Density Fiberboard* (MDF) where the main material was seaweed (*Gracilaria* sp.) to replace polybags. Any significant results were tested further using Duncan's test [14].

3. Results and discussion

The results of this study consisted of observations of the growth rate for 25 days, including stem length, leaf length and leaf diameter, and on the last day, we carried out the observation of a long root. The results of this data were the main parameters in this research. The supporting parameter data consisted of soil quality and physical data. The stem length growth rate was one of the most important parameters because it was used to determine the effective value of the volume of water used in the study. The data for the growth rate and the stem length has been shown in Figure 1.

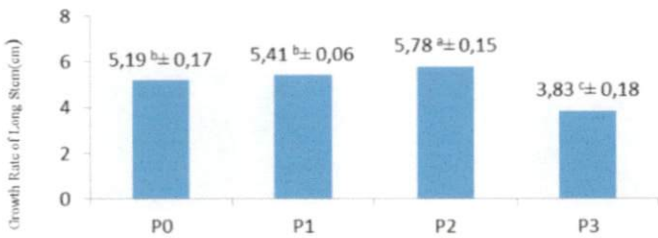

Figure 1. Bar Diagram of the Long Stem Growth Rate of *Gracilaria* sp. Description: the different superscripts on the same bar chart show very significant differences (p <0.01). P0 (volume of water 10ml daily), P1 (water volume 250ml (100%)), P2 (water volume 187.5ml (75%)), P3 (125ml (50%) water volume.

The results of stem length growth rate shown in Fig. 1 fluctuated for every treatment, and ranged from 3.83 to 5.78 cm. The highest stem length growth rate was in the second treatment and the lowest stem length growth rate was produced by the third treatment. Based on the results of the calculation of the Analysis of Variance (ANOVA), it was determined that the water volume treatment in this research was very different (p<0.01) when compared to the growth rate of the stem length. Further results of Duncan's Test allowed us to determine that the treatment of P2 was significantly different from the control treatments of P0, P1 and P3. The treatment of P1 was not significantly different from the control treatment (P0), but it was significantly different from P2 and P3.

Table 1. The growth of the tomato plant (average ± SD) - *Eucheuma cottonii*

Treatment	Day					
	5	10	15	20	25	Average±SD
P0	3.40	4.51	5.44	6.12	6.19	6.19±0.12
P1 50%	2.16	2.96	2.99	2.98	2.98	3.72±0.21
P2 75%	3.68	4.60	5.36	5.57	5.57	5.57±0.93
P3 100%	3.34	4.85	5.78	6.24	6.34	6.34±0.10

The results of this research show that the growth of the tomato plant showed there to be a very big increase in the treatment of P3, with the lowest in P1. In the treatment of P3, the pot using 100% water volume was the lowest; this is because the volume of water affects the growth of the plants. According to[12], the amount of water that is absorbed by the plant roots is dependent on the groundwater content which, in turn, is determined by the ability of the roots to absorb it. Given the water volume at P3, the treatment plants could absorb more water for growth. The P0 treatment was not much different from the P3 treatment. According to [15], watering tomato plants should be done a water dose of 250 ml at the age of 0-4 weeks, conducted morning and evening. Treatment P1 showed a slight growth due to the volume of water lacking compared to the needs of the tomato plants. Descriptively, it is known that P1 has a low growth average compared to P3, P0 and P2. Statistically ($P < 0.05$), the growth between P0, P1, P2 and P3 was significantly different, with Duncan's notation test for P3 and P0's plant growth being significantly different from the other treatments. Treatments P1 and P2 were significantly different.

The leaf growth rate was one of the most important parameters because it was used to determine the effective value of the water volume used in this research. The data of the growth rate of the leaf length has been shown in Figure 2.

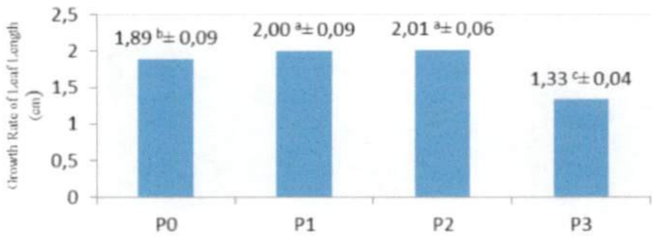

Figure 2. Bar diagram of the leaf length growth rate for *Gracilaria* sp. Description: the different superscripts used on the same bar diagram show very significant differences (p <0.01); P0 (volume of water 10ml daily), P1 (water volume 250ml (100%)), P2 (water volume 187.5ml (75%)), P3 (125ml (50%) water volume).

The results of the leaf growth rate in Fig. 2. fluctuated for each treatment, ranging from 1.33 to 2.01 cm. The highest leaf growth rate was found in the second treatment and the lowest leaf growth rate was produced by the third treatment. Based on the results of the calculation of Analysis of Variance (ANOVA), it was determined that the water volume treatment in this research was very different (p<0.01) when compared to the leaf growth rate.

The further results of Duncan's test show that the P2 treatment was not significantly different to P1. The treatment of P2 was significantly different from the control treatment of P0 and P3. The control treatment P0 was significantly different from all of the other treatments. The treatment of P3 was also significantly different from all of the other treatments.

Table 2. The length leaf (average±SD) of *Eucheuma cottonii*

Treatment	Day					
	5	10	15	20	25	Average±SD
P0	0.45	0.88	1.53	1.49	1.87	1.87±0.77
P1 50%	0.44	0.82	1.04	1.04	1.04	1.19±0.08
P2 75%	0.44	0.82	0.95	1.11	1.315	1.29±0.04
P3 100%	0.50	0.98	1.21	1.55	1.94	1.94 ±0.05

The effect of plant height is related to the addition of both the cell numbers and sizes. The plant height growth demonstrated the activity of forming xylem and enlarging the growing cells. Higher plants can yield higher yields per plant than shorter plants. This is because higher plants can prepare their vegetative organs better so then the resulting photosynthesis is more effective. To obtain higher tomato production, this needs to be supported by optimal vegetative growth such as the availability of the nutrients and other growth factors [16].

The leaf diameter growth rate is one of the most important parameters because it was used to determine the effective value of the volume of water used in this research. The data of the leaf growth rate has been shown in Figure 3.

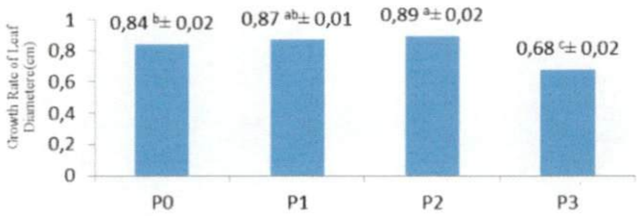

Figure 3. Bar Diagram of the Leaf Diameter Growth Rate of *Gracilaria* sp.
Description: the different superscripts on the same bar diagram show where there are very significant differences ($p < 0.01$); P0 (volume of water 10ml daily), P1 (water volume 250ml (100%)), P2 (water volume 187.5ml (75%)), P3 (125ml (50%) water volume).

The results of the leaf growth rate in Figure 3. fluctuated in each treatment, which ranged from 0.68 to 0.89 cm. The highest leaf diameter growth rate was found in the second treatment and the lowest leaf diameter growth rate was generated by the third treatment. Based on the results of the calculation by Analysis of Variance (ANOVA), it was determined that the water volume treatment in this research was very different ($p < 0.01$) when compared to the leaf growth rate. Further results of Duncan's test makes it known that the P2 treatment was not significantly different from P1. The control treatment P0 was not significantly different to P1. P3 was significantly different from all of the other treatments.

Root length growth rate is an important parameter that was used to determine the effective value of the water volume in this research. A long observation of the roots was done on the last day of the study - the 25th day. The results obtained from the root length were that they grew 3.5 cm in the water volume treatment of 187.5 ml (P2), 3.2 cm in the water volume treatment of 250 ml (P1), 3 cm in the control treatment (P0), and 2.5 cm in the 125 ml water volume treatment (P3).

Table 3. Plant leaf width (average±SD) *Eucheuma cottonii*

Treatment	Day					
	5	10	15	20	25	Average±SD
P0	0.14	0.27	0.37	0.43	0.68	0.83±0.06
P1 50%	0.14	0.35	0.46	0.45	0.53	0.46±0.03
P2 75%	0.12	0.32	0.45	0.49	0.74	0.75±0.03
P3 100%	0.08	0.24	0.33	0.46	0.67	0.80±0.07

The length and width of the leaves on the tomato plants during the research showed that the largest average value was in treatment P3 at 1.94 and the lowest was in treatment P1 at 1.19. Plant leaf width had the largest average value in treatment P0 at 0.832 and the lowest in P1 at 0.458. Statistically, the leaves of P3 and P0 were not significantly different from the other treatments but P2 and P1 were significantly different. Statistically, P0 was not significantly different from P3 but it was significantly different from P2 and P1. The length of the plant leaves and the width of the plant leaves follows the growth of the plant. If the growth of the plant is good then it means that the length and the width are good too and vice versa. Plant leaves are places where light energy is changed into chemical energy and carbohydrates or glucose, which manifests in the form of dry matter. The development of the leaves is therefore the main parameter for analyzing plant growth[17].

The effect of plant height is related to cell numbers and sizes. Plant height growth demonstrates the activity of forming xylem and promoting cell growth. Higher plants can yield higher yields per plant, more so than shorter plants. This is because higher plants can prepare their vegetative organs better so then the resulting photosynthesis will be more. To obtain higher tomato production, it needs to be supported by optimal vegetative growth factors such as the availability of nutrients and other growth factors [16].

The main factor to make a successful seaweed pot product is the providing of nutrients in the form of fertilizer. The determination of the polybag size was adjusted to the kind of plant related to root development. The polybag size varied and the use of it should be adjusted according to the age and kind of plant. The size of the pots affected the growth of the plant in height during the observation over 25 days. For the small pot size, the plant height reached an average of 6.34 cm. This is is due to the influence of the content of the pot that was 50% seaweed +50% wood powder.

Based on the research that has been done, the temperature range (29-32°C), pH (6.75) and the highest average humidity in the treatment of P3 was 7.84 while the lowest average humidity was at treatment P1 at 4.62. The tomato plants were assessed in the research by looking at the supporting parameters to examine growth. Temperatures that are too hot and too dry can cause the pot to get dry quickly and equally, damage will be caused if the temperature is too low. According to[18], tomato plants are a warm season crop with an optimum temperature range of 20-28 ° C and with a preferred soil fertility level with a pH of 5.0-7.0. The transfer of tomato plants to the enlargement site were from a tomato plant that already had 4-5 pieces of plant leaves with a spacing of 20 x 20 cm or 25 x 25 cm [19]. The results of the tomato plant growth in the study could have been moved to the enlargement spot on the 21st day of observation, because the tomato plants already had 4-5 leaves.

The soil quality data was a supporting parameter that was used to complete the data into the research on the potential of seaweed waste (*Gracilaria* sp.) as the base material used to construct a pot based on Medium Density Fiberboard (MDF) particle board and the efficient use of water volume in tomato plants. The soil quality data can be seen in Table 4.

Table 4. Data of soil quality of *Gracilaria* sp.

Parameter	P0	P1	P2	P3
Temperature	27-29 °C	27-29 °C	27-29 °C	27-29 °C
Humidity	4-6.2 pF	5-6.2 pF	4-6.2 pF	3-5 pF
pH	6.8-7	6.6-7	6.6-7	6.5-69

Description: P0 (volume of water 10ml daily), P1 (water volume 250ml (100%)), P2 (water volume 187.5ml (75%)), P3 (125ml (50%) water volume).

The physical data is a supporting parameter that was used to complete the data into the research on the potential of seaweed waste (*Gracilaria* sp.) as a pot-based material of Medium Density Fiberboard (MDF) particleboard related to the efficient use of water volume in tomato plants. The results of the physical data can be seen in Table 5.

Table 5. Physical data of *Gracilaria* sp.

Physical data	Sample 1 (Water Volume 250ml)	Sample 2 (Water Volume 187,5ml)	Sample 3 (Water Volume 125ml)
Absorption ability (%)	18,0232	11,5646	7,4866
Water content (%)	84,7058	60,7407	51,0526
Density (g/cm^3)	0,3138	0,3017	0,2316

Description: P1 (Water Volume 250ml (100%)), P2 (Water Volume 187,5ml (75%)), P3 (Water Volume 125ml (50%)).

The main parameter of the research into the potential of seaweed waste (*Gracilaria* sp.) as the base material of a pot based on Medium Density Fiberboard (MDF) particle board related to the efficient use of water volume in tomato plants was the growth rate of the tomato plants themselves. The growth rate of the tomato plants began with germination occurring on the third day, because the germination of tomato seeds occurs 3 - 5 days after the seeding [10].

The results showed that the growth rate of the tomato plants for 25 days fluctuated in each treatment, i.e. 3.83 - 5.78 cm stem length, 1.33 - 2.01 cm leaf length, 0.68 to 0.89 cm diameter Leaves, and 2.5 - 3.5 cm long roots.

The ANOVA analysis of the growth rate of the tomato plants showed that the growth rate of stem length, leaf length, and leaf diameter at different water volumes showed there to be significantly different effects (P<0,01). This is because seaweed (*Gracilaria* sp.) has the ability to absorb and store water [20]. Based on these results, the seaweed waste (*Gracilaria* sp.) can be used as a pot base in Medium Density Fiberboard (MDF) to improve the efficient use of water volume in tomato plants. The seaweed waste's function is as a substitute agent for polybags. Thiscan even be temporary because of seaweed waste (*Gracilaria* sp.) has a humidity content of 68.4% and 20.1% fiber content [21]. On the last day, the tomato plant was ready to be moved to a pot or soil medium.

The results of lignocellulose testing on the seaweed waste (*Gracilaria* sp.) showed that it had a content of 30.78%. The high content of cellulose in the seaweed waste (*Gracilaria* sp.) can be used as the base material of Medium Density Fiberboard (MDF) because the particle board consists of wood particles made of lignocellulose material[6].

Table 6. The test results of the physical properties of Medium Density Fiberboard (MDF)

Physical Properties	JIS A 5908 2003	Large pot	Small pot
Density (g/cm^3)	0.4-0.49	0.93	0.95
Water content (%)	5-13	15.13	15.97
Absorption ability (%)	Not required	23.27	15.35

Physical tests were conducted to determine the physical quality of the Medium Density Fiberboard (MDF) product that had been produced. The physical test consisted of density, absorption ability (moisture content) and water absorption using the JIS A 5908 2003 standard as a reference. Density was a test of the physical properties that showed the ratio of the mass of an object related to its volume at the equilibrium moisture content. The large pots and small pots containing the same mixture with 50% wood powder and 50% seaweed had the same yield value but for the large pot products, the temperature increased to be stronger if exposed to water. According to [22], temperature and time are pressing factors that have a very real effect that can impact on the resistance of particle board products. As seen in Table 6, the large potting products have a density of 0.93 g/cm^3 and the small pot products have a density of 0.95 g/cm^3. Temperature and timing can affect the density of the Medium Density Fiberboard (MDF) particle board products.

The test for the water content was carried out on both the large pot products and the small pot Medium Density Fiberboard (MDF) products, with the main ingredients being seaweed (*Eucheuma cottonii*). The pots were given same treatment with changes in volume in accordance with the sizes in order to determine if a standard could be applied or not. The water content standard was in accordance with JIS A 5908 2003, and was between 5-13%. According to [23], dried seaweed can absorb water vapor from the air, so the water content in the treatment of large pots and small pots had the same value that reached an average of 15.13 - 15.97

The water absorption test showed there to be a difference of 23.27% for the large pot products and 15.35% for the small pots. According to [24], the higher particle board density meant that the water absorption rate was higher too. From the results of the absorption test in large pot products, the absorption rate of the water was because the Medium Density Fiberboard (MDF) has a high density. Therefore the bond between its particles is more solid and this causes the air cavity on the slab of the product to make it difficult for water or water vapor to fill cavity. The physical properties of water absorption in th JIS A 5908 2003 standard are not required, so the large pot products and small pot products have been included as Medium Density Fiberboard (MDF) products.

The results of this research show that the treatment demonstrates a significantly different effect, supported by parameters such as temperature, humidity, soil pH, and the physical data. Tomato plants need enough sunlight but to not be too hot. The physical data consisted of water content, absorption ability and density. The results of the physical data show that the treatment of 250 ml (P1) in water volume showed the highest results because the seaweed (*Gracilaria* sp.) contains many gels that have the ability to bind water [20].

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4. Conclusion

Based on the results of this research, there were several conclusion reached. The first was that the waste from *Gracilaria* sp. and *Eucheuma cottonii* can be used as the base material for pots made out of Medium Density Fiberboard (MDF) particle board as a substitute for polybags. The optimal water volume used in the pots due to the seaweed waste of *Gracilaria* sp. can be used as a medium of growth by up to 187.5 ml. The seaweed waste of *Eucheuma cottonii* was used as a growth medium for the tomato plants as a substitute for polybags, supplying 250 ml.

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