Effect of seaweed liquid organic fertilizer in different concentrations on tomato (*Solanum lycopersicum*) growth and yield

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Abstract. The tomato plant (*Lycopersicum esculentum* Mill) is a plant that has been cultivated for hundreds of years, but it is not known with certainty when it first spread. Tomato plants come from the Americas, namely Peru. This study aims to determine the effect on the growth and yield of tomato plants of seaweed liquid organic fertilizer (LOF). This research was conducted at the Greenhouse of the Faculty of Agriculture, Tadulako University, Palu City, Indonesia. The method used in this study was a randomized block design (RBD) with 5 treatments and 3 repetitions (18 experimental units), with the following treatments: T_0 - no seaweed LOF (control); T_1 - 10 cc LOF/L water; T_2 - 20 cc LOF/L water), T_3 - 30 cc LOF/L water; T_4 - 40 cc LOF/L water; and T_5 - 50 cc LOF/L water. The results showed that the application of LOF made from seaweed significantly affected on the growth and yield of tomato plants. Treatment P5 performs better than other treatments.

Key Words: healthy, microorganism, nutrient, sustainable.

Introduction. The tomato plant (*Lycopersicum esculentum* Mill) is a plant that has been cultivated for hundreds of years, but it is not known with certainty when it first spread. Historically, tomato plants originated in America, namely the Andean region, which is part of the countries of Bolivia, Chile, Colombia, Ecuador, and Peru (Vinoth et al 2017).

Tomatoes are classified as multipurpose and multifunctional fruit vegetables that can be cultivated in lowland or highland. It is in the form of a shrub. The leaves are green and present slit insertions, being arranged on the stalk. The shape of the fruit is round, flat, or oval. The color of the fruit is green at first, and after ripening, it is red (Aghaie et al 2018). Ripe tomatoes are very popular because of their taste. The fruit contains much water, stores a large number of seeds, contains vitamins A and C, and a small amount of vitamin B. The tomato fruit contains many substances useful for the human body, including vitamin C, vitamin A (carotene), and minerals (Ali et al 2016). Tomatoes function not only as vegetables or fruit, but are also often used as cooking spices, in fresh drinks, as sources of vitamins and minerals, and as natural coloring agents. Tomatoes can also be used as ingredients for cosmetics or medicines (Vinoth et al 2017).

The low production of tomato plants can be caused by disease-sensitive cultivars, low seed quality, inappropriate farming techniques, and environmental conditions that do not optimally support plant growth. For the growth and production of tomato plants to be optimal, various treatments are needed, including proper and balanced fertilization and the use of seeds from superior varieties. Fertilization aims to meet the availability of nutrients needed by plants. Fertilizers for plant growth can be administered directly to plants or through leaves (Maghfoer et al 2014; Aghaie et al 2018).

The application of fertilizer through the leaves must be carried out properly, both in the type of application, concentration, and time of application (Finnie & Van Staden 1985). The use of the proper concentration is a factor that will determine the benefits of the fertilizer. Plant growth will worsen if the concentration is less or more than the recommended concentration. If given the right concentration, time, and method of action, the fertilizer sprayed on the leaves is relatively easy to be absorbed by plants and avoids damage to the physical and chemical properties of the soil. Fertilization through leaves by organic fertilizer can relatively improve soil quality (Vijayanand et al 2014; Manimaran et al 2018). Fertilizers are natural or artificial substances added to the soil, which can increase its fertility by adding one or more essential nutrients. Fertilizers can be divided into organic and inorganic fertilizers. The liquid organic fertilizer is a solution resulting from the decomposition of organic materials derived from plant residues, animal and human wastes, which contains more than one nutrient element. In general, liquid organic fertilizers do not damage the soil and plants, even though they are often used (Chouliaras et al 2009).

Unlike chemical fertilizers, seaweed liquid organic fertilizers (LOF) are naturally biodegradable, non-toxic, non-contaminating, and safe for humans and animals. The use of seaweed as a fertilizer or as a fertilizer additive is expected to be an alternative to solving environmental problems because it is safe for soil microbes and plants and also increases the economic value of seaweed in Indonesia. Several methods of making seaweed liquid fertilizer have been tested previously, including the physical extraction of fresh seaweed liquid, as well as extraction using alkali (Basmal 2009; Sedayu et al 2013). This study aims to determine the effect of seaweed LOF in different concentrations on the growth and yield of tomato plants.

Material and Method

Study area. This research was carried out under greenhouse conditions at the Faculty of Agriculture, Tadulako University, Indonesia. The tools used in this study were shovels, polybags, buckets, cameras, rulers, scissors, ropes, scales and others. At the same time, the materials needed in this study were EM4, tomato seeds, sugar, water, and seaweeds. This study used a Randomized Block Design method, which consisted of five levels of seaweed LOF treatments: T_0 - 0 cc/1 L water (control); T_1 - 10 cc/1 L water; T_2 - 20 cc/1 L water; T_3 - 30 cc/1 L water; T_4 - 40 cc/1 L water; T_5 - 50 cc/1 L of water. Each of the six treatments was repeated three times so that the total experiment unit was eighteen. The LOF made from seaweed was sprinkled on the soil surface.

Seed preparation. After the seeds were selected, they were immediately planted on the prepared seedling media. The seedling media used was soil mixed with chicken manure and roasted husks 1:1:1, filled into the prepared nursery gutters, sprinkled with water, covered with a thin layer of soil, then stored in a place protected from moisture and exposure to direct sunlight. After four days, it was opened and stored under natural light, but not exposed directly to sunlight.

Seaweed preparation. Seaweed LOF was made from *Sargassum* sp. collected from Banggai Laut District of Central Sulawesi Province in Indonesia. The seaweed LOF was obtained through a fermentation process as the result of the decomposition of organic matter by adding EM4 decomposing microorganisms to accelerate the process. The LOF was obtained by thoroughly washing the seaweed and slicing it. 1 kg of seaweed was used. 3 L of water, 50 mL of EM4, and 500 g of sugar were added to the seaweed, and the composition was mixed in a plastic container and stirred until homogeneity was obtained. The container was closed hermetically and left for 15 days.

Medium preparation. The preparation of the planting media used in this study was soil that had been air-dried and sifted, and manure. Soil and manure were stirred and placed in prepared polybags, in a ratio of 2:1. Planting was carried out after the plants had 15 days after sowing (DAS). The seeds were removed one by one from the nursery to be transferred to the planting polybags that have been prepared. Before planting, the planting medium was watered. 45 plants were planted in polybags, having a distance of 30x30 cm in one treatment block. Watering was conducted every morning and evening, depending on local environmental conditions. Seaweed LOF application was made by spraying it on soil. The seaweed LOF application in this study followed the concentration test application at the age of 15, 30, and 45 days after planting. The installation of bamboo stakes for plant support was carried out at two weeks after planting, with lengths of stakes ranging between 140-150 cm. The tomato fruits were harvested at 84, 87, 90, 93, and 96 DAP. The plants were harvested by twisting the fruit carefully until the fruit stalk was cut off. The harvesting of the fruit was done one by one, fruits being considered ripe when the skin color changed from green to reddish yellow. The tomatoes were harvested every three days in the afternoon.

Parameter measurement. The observations consisted of two stages, namely in the vegetative and generative growths.

The plant height (cm) was observed at 14, 21, 28, and 35 DAP ages. Measurements were conducted from the base of the stem to the growing point or shoot of the plant.

The number of leaves was measured at the age of 14, 21, 28, and 35 DAP.

The diameter of the stem's base (cm) was observed at ages of 14, 21, 28, and 35 DAP.

The number of fruits per plant measures the total number of fruits of each plant by adding the fruits from the first to the fifth harvesting such as 84, 87, 90, 93 and 96 DAP.

The fresh fruit weight per plant (g) was measured from the first harvesting to the fifth harvesting.

The plant fresh weight (g) was determined by weighing the plants, including stems, leaves, and tiny fruits, at the same time.

The plant dry weight (g) measurements were carried out by weighing the plants, stems, leaves, and fruits at the same time after being in an oven for 48 h at 80^{o}C.

This study used the variance analysis (ANOVA), α=0.05. If the variance analysis showed a significant effect of the treatment, the 5% Honestly Significance Difference (HSD) test was conducted to determine the pairs of data sets with significant differences.

Results and Discussion. The analysis of variance showed that some of the treatments with seaweed LOF had significant effects on tomato plant height. The average plant height is listed in Table 1.

Table 1

Average tomato plant height (cm) in treatments with seaweed liquid organic fertilizer (LOF)

Treatments	*Plant age*			
	14 DAP	*21 DAP*	*28 DAP*	*35 DAP*
T_0	20.26±1.21^{a}	28.96±4.74^{a}	45.73±1.77^{a}	57.59±11.84^{a}
T_1	19.05±1.55^{a}	31.94±5.99^{a}	65.6±11.05^{ab}	68.89±9.83^{ab}
T_2	21.60±2.27^{ab}	33.34±6.24^{a}	62.63±3.14^{ab}	83.45±094^{bc}
T_3	23.72±1.26^{ab}	34.49±3.75^{ab}	62.55±6.60^{ab}	85.33±2.32^{bc}
T_4	21.26±1.93^{a}	39.89±0.45^{ab}	69.82±6.15^{ab}	91.79±1.63^{c}
T_5	26.80±1.20^{b}	48.38±4.71^{b}	82.60±4.16^{b}	96.01±3.84^{c}
HSD 5%	4.89	14.43	35.05	18.68

Note: T_0 - 0 cc LOF /1 L water (control); T_1 - 10 cc LOF/1 L water; T_2 - 20 cc LOF/1 L water; T_3 - 30 cc LOF/1 L water; T_4 - 40 cc LOF/1 L water; T_5 - 50 cc LOF/1 L of water; DAP - days after planting; different superscripts in the same column indicate significant differences ($p<0.05$).

The 5% HSD test (Table 1) showed that the tomato plants with the biggest average height at 14 DAP was obtained in treatment T_5, which was 26.8±1.2 cm, significantly higher than the results obtained in T_0, T_1, and T_4, respectively but not different from the other treatments. At 14 DAP, the average highest plant was obtained in T_5, with 48.38±4.71 cm, different from T_0, T_1, and T_2, but not different from T_3 and T_4. At 28 DAP, the highest average was obtained in T_5, 82.6±4.16 cm, different from T_0, but not different from the other treatments. At 35 DAP, the highest average was obtained in T_5, 96.01±3.84 cm, different from T_0 and T_1, but not different from the other treatments.

Number of leaves. The analysis of variance showed that the treatment of seaweed LOF concentration had a significant effect on the number of leaves of tomato plants. The average number of leaves is listed in Table 2.

Table 2

Average number of tomato plant leaves in the treatments with seaweed liquid organic fertilizer (LOF)

Treatments	*Plant age*			
	14 DAP	*21 DAP*	*28 DAP*	*35 DAP*
T_0	15.22±2.06^{a}	22.66±8.18^{a}	37.89±8.58^{a}	45.67±8.73^{a}
T_1	16.55±3.38^{a}	30.43±5.61^{ab}	56.66±15.21^{ab}	64.44±21.10^{ab}
T_2	19.00±3.81^{ab}	39.89±18.73^{ab}	59.78±11.97^{ab}	70.33±10.65^{ab}
T_3	21.11±1.57^{ab}	40.89±10.64^{ab}	55.33±13.03^{ab}	58.44±10.62^{a}
T_4	17.89±2.20^{ab}	40.44±18.53^{ab}	65.67±5.31^{ab}	77.78±9.45^{ab}
T_5	26.44±3.94^{b}	51.67±19.36^{b}	84.00±5.89^{b}	95.78±6.24^{b}
HSD 5%	9.86	24.13	30.99	35.48

Note: T_0 - 0 cc LOF /1 L water (control); T_1 - 10 cc LOF/1 L water; T_2 - 20 cc LOF/1 L water; T_3 - 30 cc LOF/1 L water; T_4 - 40 cc LOF/1 L water; T_5 - 50 cc LOF/1 L of water; DAP - days after planting; different superscripts in the same column indicate significant differences ($p<0.05$).

The 5% HSD test (Table 2) showed that the number of leaves of tomato plants at the age of 14 DAP was highest in T_5 treatment, 26.44±3.94, significantly different from T_0 and T_1. At 21 DAP, the highest average was obtained in T_5, 51.67±19.36 leaves, significantly different from T_0. At age 28 DAP, T_5 had the highest value, with 84±5.89 leaves, different from T_0. At age 35 DAP, again T_5 had the highest value, 95.78±6.24 leaves, different from T_0 and T_3, but not different from other treatments.

Stem diameter. The average stem diameter is presented in Table 3. Some treatments had a significant effect on the stem diameter at different ages.

Table 3

Average stem circumference of tomato plants (mm) in treatments with seaweed liquid organic fertilizer (LOF)

Treatments	*Plant age*			
	14 DAP	*21 DAP*	*28 DAP*	*35 DAP*
T_0	2.77±0.35^{a}	3.43±0.15^{a}	4.10±0.38^{a}	4.44±0.42^{a}
T_1	3.11±0.43^{ab}	3.94±0.39^{ab}	5.99±0.33^{bc}	6.49±0.34^{bc}
T_2	3.23±0.09^{ab}	4.12±0.09^{abc}	5.56±0.11^{b}	6.56±0.16^{bc}
T_3	3.47±0.13^{ab}	4.41±0.15^{bc}	5.55±0.64^{b}	6.04±0.32^{b}
T_4	3.12±0.36^{ab}	4.97±0.33^{cd}	5.42±0.29^{b}	5.95±0.21^{b}
T_5	3.48±0.05^{b}	5.25±0.13^{d}	6.78±0.56^{c}	7.32±0.27^{c}
HSD 5%	0.62	0.80	1.12	0.92

Note: T_0 - 0 cc LOF /1 L water (control); T_1 - 10 cc LOF/1 L water; T_2 - 20 cc LOF/1 L water; T_3 - 30 cc LOF/1 L water; T_4 - 40 cc LOF/1 L water; T_5 - 50 cc LOF/1 L of water; DAP - days after planting; different superscripts in the same column indicate significant differences ($p<0.05$).

The results of the HSD 5% test (Table 3) showed that the largest stem circumference of tomato plants at 14 DAP was obtained in T_5, 3.48±0.05 mm, significantly different from T_0. At the age of 21 DAP, plants in T_5 had again the largest stem diameter, 5.25±0.13 mm, significantly different from T_0, T_1, T_2, and T_3. At the age of 28 DAP, the largest stem average was obtained in T_5, 6.78±0.56 mm, significantly different from T_0, T_2, T_3, and T_4. At the age of 35 DAP, the largest stem average was obtained in T_5, 7.32±0.27 mm, significantly different from treatments T_0, T_3, and T_4.

Fresh weight of fruits per plant. The analyses of variance showed that the treatment of seaweed with LOF had no significant effect on the total fresh weight of fruit. Figure 1 shows that the average value of the fresh weight of tomatoes from a plant tends to be the highest in treatment T_5, 1683.09±695.07 g, while the lowest was in T_0 (control), 906.51±326.9 g.

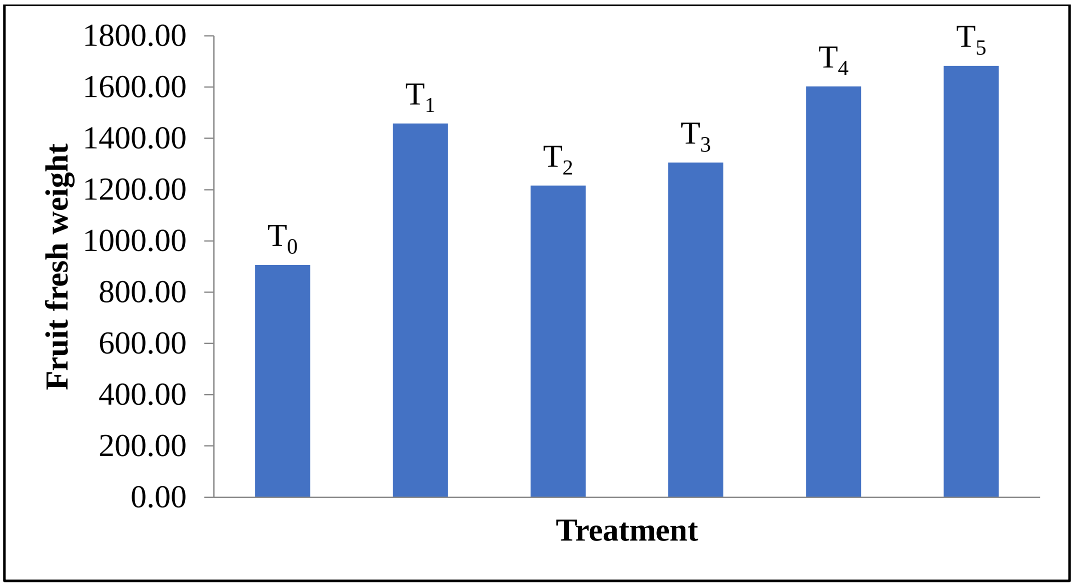

Figure 1. The total average fresh weight of tomatoes per plant (g) in the treatments with seaweed liquid organic fertilizer; T_0 - 0 cc LOF /1 L water (control); T_1 - 10 cc LOF/1 L water; T_2 - 20 cc LOF/1 L water; T_3 - 30 cc LOF/1 L water; T_4 - 40 cc LOF/1 L water; T_5 - 50 cc LOF/1 L of water; LOF - liquid organic fertilizer.

Number of fruits. The analysis of variance showed that the treatments had no significant effect on the number of fruits aged 84 DAP, but had a significant effect on those aged 87, 90, 93, and 96 DAP. The average number of fruits is listed in Table 4

Table 4

Average number of tomatoes per plant in the treatments with seaweed liquid organic fertilizer

Treatments	*Plant age*				
	84 DAP	*87 DAP*	*90 DAP*	*93 DAP*	*96 DAP*
T_0	2.22	$2.22±0.31^{a}$	$2.66±0.54^{a}$	$3.89±0.83^{ab}$	$6.00±0.82^{a}$
T_1	2.00	$2.77±0.16^{ab}$	$3.11±0.42^{ab}$	$3.22±0.57^{a}$	$11.33±2.33^{ab}$
T_2	2.33	$3.00±0.27^{abc}$	$4.00±0.82^{ab}$	$3.77±0.68^{ab}$	$13.22±0.88^{ab}$
T_3	3.22	$3.66±0.27^{bc}$	$3.89±0.42^{ab}$	$4.22±0.31^{bc}$	$11.89±2.22^{ab}$
T_4	3.44	$3.89±0.16^{c}$	$4.55±0.16^{b}$	$4.89±0.79^{cd}$	$14.89±2.53^{b}$
T_5	3.00	$3.66±0.27^{c}$	$4.55±0.42^{b}$	$5.55±0.57^{d}$	$14.67±4.55^{b}$
HSD 5%	-	0.91	1.65	0.89	7.97

Note: T_0 - 0 cc LOF /1 L water (control); T_1 - 10 cc LOF/1 L water; T_2 - 20 cc LOF/1 L water; T_3 - 30 cc LOF/1 L water; T_4 - 40 cc LOF/1 L water; T_5 - 50 cc LOF/1 L of water; DAP - days after planting; different superscripts in the same column indicate significant differences ($p<0.05$).

The 5% HSD test (Table 4) showed that the highest number of tomatoes per plant was at 87 DAP, obtained in T_4, 3.89±0.16 fruits, significantly different from T_0 and T_1. At the age of 90 DAP, the highest number of tomatoes per plant was in T_4 and T_5, significantly different from T_0. At the age of 93 DAP, the highest number was obtained in T_5, 5.55±0.57 fruits, significantly different from T_0, T_1, T_2, and T_3. At 96 DAP, the highest number was obtained in T_4, 14.89±2.53 fruits, significantly different from T_0, but not from the other treatments.

Plant fresh weight. The analysis of variance showed that the treatments with seaweed LOF had no significant effect on the fresh weight of the plant. The average plant fresh weight is presented in Figure 2.

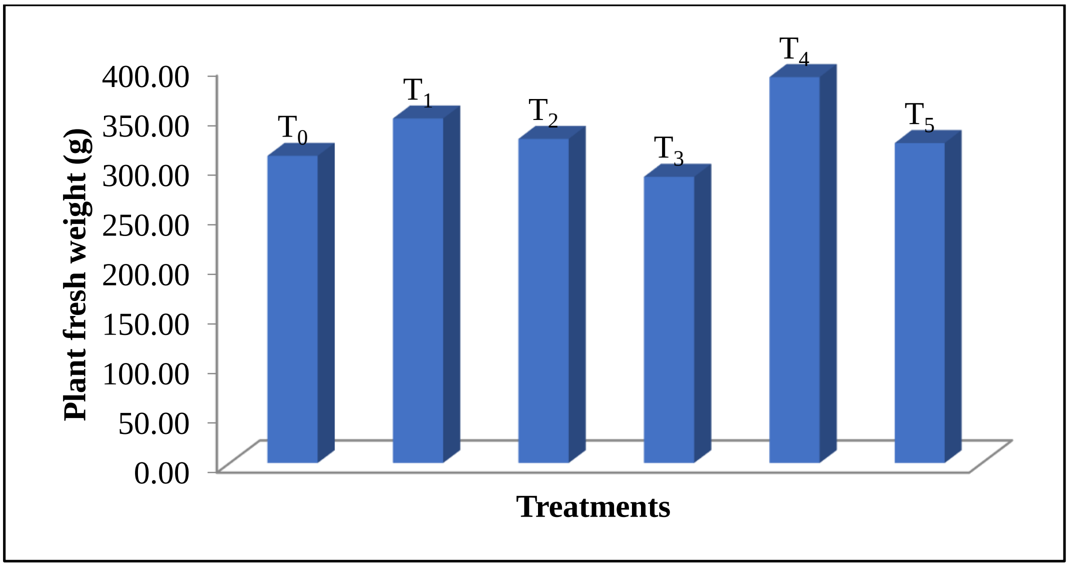

Figure 2. Average overall fresh weight of tomato plants (g); T_1 - 10 cc LOF/1 L water; T_2 - 20 cc LOF/1 L water; T_3 - 30 cc LOF/1 L water; T_4 - 40 cc LOF/1 L water; T_5 - 50 cc LOF/1 L of water; LOF - liquid organic fertilizer.

Figure 2 shows that the average fresh weight of tomato plants tended to be higher in T_4, namely 388.89±27.33 g, while it tended to be lower in T_3, with 288.87±49.59 g.

Plant dry weight. The results of variance showed that the treatments had a significant effect on the dry weight of plants. The average dry weight of plants is presented in Table 5. The 5% HSD test (Table 5) showed that the heaviest dry weight of tomato plants was obtained in T_4, 90.11±20.77 g, significantly different from T_0.

Table 5

Average dry weight of tomato plants (g) in treatments with seaweed liquid organic fertilizer

Treatment	*Plant age*
	100 DAP
T_0	51.88 ± 7.83^{a}
T_1	84.00 ± 6.92^{ab}
T_2	80.10 ± 11.55^{ab}
T_3	77.87 ± 3.35^{ab}
T_4	90.11 ± 20.77^{b}
T_5	79.37 ± 11.10^{ab}
HSD 5%	32.39
HSD 5%	32.39

Note: T_0 - 0 cc LOF /1 L water (control); T_1 - 10 cc LOF/1 L water; T_2 - 20 cc LOF/1 L water; T_3 - 30 cc LOF/1 L water; T_4 - 40 cc LOF/1 L water; T_5 - 50 cc LOF/1 L of water; DAP - days after planting; different superscripts in the same column indicate significant differences ($p<0.05$).

The study showed that the treatments with seaweed LOF significantly affected the experimental parameters such as plant height, the number of leaves, stem diameter, and fruit weight. Applying LOF can improve soil's physical, chemical, and biological properties. Organic matter is an adhesive source of plant nutrients and a source of energy for most soil organisms (Quilty & Cattle 2011; Moubayed et al 2017).

The treatment without fertilizer application gave the lowest plant height. In contrast, tomato plants with seaweed LOF gave significantly higher plant heights. The application of LOF must consider the right concentration and pay attention to the cultivated plants. Using the right concentration of liquid organic fertilizer can improve growth, accelerate harvesting, extend the production period or life, and increase crop yields. This is because organic fertilizers contain nutrients, especially nitrogen (N), phosphorus (P), and potassium (K), but also have other roles that affect plant growth, development, and health (Vijayanand et al 2014; Wang et al 2017). They also contain macro mineral components, such as calcium, manganese, and potassium, and micro minerals, such as zinc, iron, and cobalt. It also contains phytohormones as growth regulators (Michalak et al 2016; Yusuf et al 2020).

Many seaweed-based products have been used as additional nutrients and as biostimulants or organic fertilizers to increase plant growth and yield. From the results of this study, it is indicated that seaweed LOF contains substances that can improve the mechanism of plant growth. Although the working mechanisms can not be fully understood, a strong suspicion of good substances at high concentrations can be demonstrated in this study, where higher concentrations produce better growth than lower concentrations.

Organic matter plays a role in improving the structure of the soil, increasing the ability to hold water and stabilizing the soil temperature (Ouzounidou et al 2016). Leaves are an essential organ for plants where photosynthesis process occur (Xu & Leskovar 2015).

Based on the average number of leaves in this study, the effects of the treatments are significant. This shows that the application of liquid organic fertilizer has a vital role in the process of plant metabolism, namely in the synthesis of amino acids and proteins from ammonium ions (Möller & Smith 1998; Halpern et al 2015).

The number of leaves on tomato plants using seaweed LOF was highest at a concentration of 50 cc LOF/L of water, while the lowest was in the treatment with a concentration of 10 cc LOF/L of water. The stem diameter of tomato plants had changed from week to week significantly, especially at the concentration of 50 cc LOF\L of water. This is evidence that seaweed LOF affects the growth of tomato plant stems.

The number of tomato plants also supports the use of LOF, with most fruits at harvests 87 and 96 DAP when applying with 40 cc/L of water, and at harvests 90 and 93 DAP when applying 50 cc/L of water. The lowest harvest was in the control.

Conclusions. A practical application to give the best results on tomato plant growth and yield is the treatment with 50 cc LOF/L of water. This treatment is the most effective because it produces the highest values for all parameters. However, further research on a field experiment on tomato plants must be conducted.

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Conflict of Interest. The authors declare that there is no conflict of interest.

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