Response of lettuce (*Lactuca sativa L.*) grown in hydroponic system to different substrate compositions and liquid organic fertilizer concentrations

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Abstract

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A study was conducted to assess the response of lettuce plants grown in a hydroponic system to different substrate compositions and liquid organic fertilizer concentrations. The study was carried out at the experimental farm of the Faculty of Agriculture, University of Halu Oleo, Kendari, Southeast Sulawesi, Indonesia, from November 2018 to January 2019. The two-factor experiment was arranged based on the Randomized Block Design. The first factor tested was three levels of different compositions of growing media (M), i.e. rice husk biochar (M1), rice husk biochar + sand (2:1 w/w; M2), and rice husk biochar + sand (1:1 w/w; M3), while the second factor was three levels of liquid organic fertilizer (LOF) of Moringa oleifera leaves + banana corm + coconut water + brown sugar at a rate of 0 (F0), 0.5% (F1), and 1% (F2), consecutively. Each combination of treatments was replicated three times. Parameters observed were plant height, number of leaves, plant fresh weight and dry weight. The results of the study revealed that the best lettuce response was found when the media rice husk biochar + sand at a ratio of 2:1 (w/w) and liquid organic fertilizer at a rate of 1% were given, as indicated by plant height, number of leaves, plant fresh and dry weight.

Key words: liquid organic fertilizer, Moringa oleifera, banana corm, rice husk biochar, lettuce

Introduction

Lettuce (*Lactuca sativa* L.) is one of nutritious vegetables. It contains calcium, phosphorous, iron, fat, carbohydrate, and vitamin A, B and C (Sunarjono, 2007; Setyaningrum dan Saparinto, 2011; Sastradiharja, 2011; Cahyono, 2014). Its high nutrient contents make the demand for the vegetable continue to rise in Indonesia, and thus a profitable commodity to grow.

The ideal growth of lettuce is highly influenced by soil fertility. the availability of arable land and inorganic fertilizer. At present the availability of arable land is getting narrower and the availability of inorganic fertilizer is uncertain and the price is increasingly expensive. One effort to overcome this is by cultivating plants without soil (hydroponic system) and application of fertilizers from various agricultural wastes (LOF) as a substitute for inorganic fertilizers.

The growing media used in hydroponics especially the hydroponic substrate system must meet the requirements of light, porous and clean (Prihmantoro & Indriani, 2005). The mixture of growing media of sand and rice husk biochar is one alternative as a growing medium in the hydroponic substrate system. Sand does not contain toxic materials, its pH is 6.0-7.5 and measuring 0.05-0.8 mm, can create porous and good aeration conditions, but has a very low moisture capacity and low nutrient content (Jones & Benton, 2005; Rubatzky, 1995). This drawback can be overcome with rice husk biochar because it can maintain the growing medium moisture. In addition, the rice husk biochar contains elements of N, P, K, Ca, and Mg and has a pH of 6-7 after being immersed for 2 days (Cuninoa et al., 2018). The composition of rice husk biochar is mostly occupied by SiO_2 (52%), C (31%), Fe_2O_3, K_2O, MgO, Cao and Cu so that the rice husk biochar has chemical properties similar to soil (Wuryaningsih, 1997).

In addition to growing media, nutrient formulation is very important in hydroponic cultivation. Haryanto et al. (2003) states that the solution given to hydroponic systems must contain macro and micro nutrients which are given regularly and efficiently. Macro and micro nutrients can be sourced from alternative organic liquid fertilizers (LOFs), namely from plant parts or agricultural waste products (Mulyani, 2002). One of the waste / parts of plants that can be used as a mixture for LOF is Moringa leaves. Sutjijanto (2014) states that extracted Moringa leaves contain a type of cytokinin hormone that can increase plant growth.

Besides Moringa leaves, banana corm can also be used as liquid organic fertilizer. The content of banana corm organic compounds play a role in the vegetative growth of plants and plants become tolerant to disease. High phenolic acid banana corm contains help bind Al, Fe and Ca ions and increase available phosphorus (Setianingsih, 2009). Banana corm contains 66% carbohydrates, protein, water, and essential elements (Suhastyo, 2011).

The right combination of the two materials both from the aspect of LOF concentration and the composition of the growing media is expected to increase the growth and yield of lettuce cultivated hydroponically both in quantity and quality. For this reason, research on the response of Lettuce Plants to the Hydroponic Substrate System with Differences in the Composition of the Growing Media and the Concentration of Liquid Organic Fertilizer (LOF).

Materials and Methods

Study site. The study was conducted in the experimental farm of the Faculty of Agriculture (4°00'45.0"S 122°31'33.1"E), University of Halu Oleo, Kendari, from November 2018 to January 2019. The materials used were 20 cm x 35 cm polybags, lettuce seeds, rice husk biochar, sand, and liquid organic fertilizer (LOF) of Moringa leaves and banana corm. The tools used were pH meters, EC meters, scales, measuring tapes, hand sprayers, watering cans, cameras, and stationery.

Experimental design. The two-factor experiment was arranged according to the randomized block design (RBD). The first factor was three levels of hydroponic substrate, i.e.: rice husk biochar (RHB) (M1); RHB + sand (2:1 w/w) (M2), and RHB + sand (1: 1 w/w) (M3), while the second factor was three levels of liquid organic fertilizer

(LOF) of Moringa leaves and banana corm, i.e. 0 (F0); 0.5% (F1), and 1% (F2). Each treatment was replicated 3 times and 4 lettuce seedlings were grown per experimental unit (per polybag).

Preparation of LOF. LOF was prepared from 500 g of Moringa leaves, 500 g of banana corm, 3 l of coconut water and 250 g of brown sugar. Moringa leaves and banana corm were first mixed and then crushed with a blender, collected in a bucket, and then added with coconut water and brown sugar. All ingredients were thoroughly stirred to produce a uniform mixture and then covered with bucket lid and left undergoing fermentation for two weeks. During the fermentation, the lid was opened for 5 minutes a day to vent the produced gases out.

Nursery and planting. Lettuce seeds were sown on a nursery tray prefilled with a growing medium of rice husk biochar and sand (1:1 w/w). Each chosen seedling was transplanted into a 8x12 cm polybag containing hydroponic substrate 29 days after sowing at which it had formed 4-5 leaves. Plant transplantation was conducted in the morning to minimize heat stress.

LOF application. LOF was given to the substrate in the morning up to harvest at an interval of 2 days. The amount of LOF was given depending on plant age or plant size, i.e. 250 ml of LOF was given per each plant up to 21 DAP (days after planting), and 500 ml of LOF was given up to harvest. Plants with F0 treatment were watered every 2 days at a volume of 250 ml (up to 3 DAP) and 500 ml forward.

Measurements. Measurements were conducted at harvest time (34 DAP). Parameters observed were plant height, number of leaves, plant fresh weight and dry weight (after being dried in the oven at 80 °C for 48 hours).

Data analysis. The analysis of variance was performed at a significance level of 95%, and the Duncan's Multiple Range Test ($P<0.05$) was conducted whenever the Anova showed a significant difference. Both ANOVA and DMRT were carried out with SPSS 22.

Results and Discussions

Results

The Anova showed that the hydroponic substrate and LOF had a significant interaction effect on the number of leaves, and the plant fresh and dry weight at 34 days after planting (DAP). Its corresponding Duncan's multiple distance test results is presented in Tables 1, 2 and 7, respectively.

As indicated in Table 1, the highest number of leaves (12.63 leaves) was obtained shows that the average number of leaves of lettuce in the interaction of the composition of the growing media without LOF (F0), the average number of leaves was obtained in the treatment of rice husk and sand 2: 1 (M2) that is 12.63 leaves, significantly different from the treatment rice husk biochar (M1) and rice husk biochar and sand 1: 1 (M3) with an average number of leaves of 10.37 and 9.30 leaves. In the treatment of LOF concentration of 5 ml / l water (F1), the average number of leaves was obtained in the treatment of rice husk and sand 1: 1 (M3) which is 14.00 leaves, significantly different from the treatment of rice husk biochar (M1) and treatment of rice husk biochar and sand 2: 1 (M2) with an average number of leaves of 12.17 and 12.70 leaves, respectively. In the treatment of LOF concentration of 10 ml / l water (F2), the highest average number of leaves was obtained in the M2 treatment of 14.27 leaves, significantly different from the M1 treatment of 11.57 leaves, but not significantly different from the M3 treatment of 12.9 leaves.

The interaction of LOF concentrations in the rice husk biochar (M1) growing media, the average number of leaves obtained in the F1 treatment was 12.17 leaves, significantly different from the F0 treatment which was 10.37 leaves, but it was not significantly different from the F2 treatment which was 11.57 leaves. In the treatment of 2: 1 (M2) rice husk biochar and sand growing media, the average number of leaves was obtained in F2 treatment, which was 14.27 leaves, significantly different from F0 treatment, which was 12.63 leaves and F1 was 12.70 leaves. The treatment of rice husk biochar and sand growing media 1: 1 (M3), the average number of leaves obtained in

the F1 treatment was 14.00 leaves, significantly different from the F0 and F2 treatments with an average number of leaves 9.30 leaves and 12.9 leaves.

Table 2 shows that the average wet weight of the lettuce plants in the interaction of the composition of the growing media without LOF (F0), the highest average wet weight was obtained in the treatment of rice husk biochar and sand 2: 1 (M2) which is 19.57 g, significantly different from treatment of rice husk biochar (M1) and rice husk biochar and sand 1: 1 (M3) with average plant fresh weight of 12.44 g and 17.37 g, respectively. In the treatment of LOF concentration of 5 ml / l water (F1), the highest average plant fresh weight obtained in the M3 treatment was 16.82 g, significantly different from the M1 treatment which was 12.63 g, but it was not significantly different from the M2 treatment which was 16.22 g. In the treatment of LOF concentration of 10 ml / l water (F2), the highest average plant fresh weight obtained in the M2 treatment was 19.67 g, significantly different from the M1 treatment which was 14.59 g, but it was not significantly different from the M3 treatment which was 18.85 g.

Interaction of LOF concentration in the treatment of rice husk biochar (M1) growing media composition, the highest average plant fresh weight obtained in F2 treatment was 14.59 g, significantly different from the F0 and F1 treatments with an average wet weight of 12.44 g and 12.63 g. In the treatment of rice husk biochar and sand 2: 1 (M2) growing media composition, the highest average wet weight was obtained in F2 treatment, which was 19.67 g, not significantly different from F0 treatment, but significantly different from F1 treatment with average weight wet 19.57 g and 16.22 g. In the treatment of 1: 1 (M3) husk biochar and sand biochar growing media, the highest average wet weight was obtained in F2 treatment, which was 18.85 g, significantly different from F1 treatment, but not significantly different from F0 treatment with average weighting wet respectively 16.82 g and 17.37 g.

Table 3 shows that the average dry weight of the lettuce plants in the interaction of the composition of the growing media with no LOF (F0), the highest average dry weight of the crop was obtained in the treatment of rice husk biochar and sand biochar growing media 2: 1 (M2) that is 6.63 g , not significantly different from the treatment of rice husk biochar and sand biochar 1: 1 (M3) with an average dry weight of 6.37 g, but significantly different from the treatment of rice husk biochar growing media (M1) with a dry weight of 4.17 g. In the treatment of LOF concentration of 5 ml / l water (F1), the highest average plant dry weight obtained at M3 treatment was 6.70 g, significantly different from the M1 and M2 treatments with average plant dry weight respectively 4.77 g and 5.27 g. In the treatment of LOF concentrations of 10 ml / l water (F2), the highest average plant dry weight obtained in the M2 treatment was 7.70 g, significantly different from the M1 and M3 treatments with the average plant dry weight respectively 5.83 g and 5.57 g.

Interaction of LOF concentration in the treatment of rice husk biochar (M1) growing media composition, the highest average plant dry weight obtained in F2 treatment was 5.83 g, significantly different from F0 treatment, but not significantly different from F1 treatment with average plant dry weight each - that is 4.17 g and 4.77 g. In the treatment of rice husk biochar and sand biochar growing media 2: 1 (M2), the highest average plant dry weight obtained at P3 treatment was 7.70 g, significantly different from F1 and F0 treatments with an average dry weight of 5.27 g and respectively 6.63 g. Treatment of rice husk biochar and sand biochar growing media 1: 1 (M3), the highest average plant dry weight obtained in treatment F1 is 6.70 g, not significantly different from treatment F0, but significantly different from treatment F2 with average plant dry weight each - that is 6.37 g and 5.57 g.

Discussions

One of essential factors that determine plant growth and yield is the growing media. The growing media in a soilless system, in particular, should possess ideal chemical and physical properties because of which plants are capable of accessing sufficient amount of nutrients and water and oxygen throughout their life cycle

Table 1. The interaction effect of hydroponic substrate and LOF on the number of lettuce leaves at 34 DAP according to DMRT (P<0.05)

	Rates of LOF (ml/l water)		
	0 (F_0)	5 (F_1)	10 (F_2)
RHB (M_1)	10.37 ^{q} $_{b}$	12.17 ^{p} $_{b}$	11.57 ^{pq} $_{b}$
RHB + sand (2:1) (M_2)	12.63 ^{q} $_{a}$	12.70 ^{q} $_{b}$	14.27 ^{p} $_{a}$
RHB + sand (1:1) (M_3)	9.30 ^{r} $_{b}$	14.00 ^{p} $_{a}$	12.90 ^{q} $_{ab}$
DMRT α0.05	2=1.40 3=1.47		

Note: Values in the same column (a, b, c) and row (p, q, r) followed by the same letter indicate insignificant difference according to DMRT (P<0.05)

Table 2. The interaction effect of hydroponic substrate and LOF on the lettuce fresh weight at 34 DAP according to DMRT (P<0.05)

	Rates of LOF (ml/l water)		
	0 (F_0)	5 (F_1)	10 (F_2)
RHB (M_1)	12.44 ^{q} $_{c}$	12.63 ^{q} $_{b}$	14.59 ^{p} $_{b}$
RHB + sand (2:1) (M_2)	19.57 ^{p} $_{a}$	16.22 ^{q} $_{a}$	19.67 ^{p} $_{a}$
RHB + sand (1:1) (M_3)	17.37 ^{pq} $_{b}$	16.82 ^{q} $_{a}$	18.85 ^{p} $_{a}$
DMRT α0.05	2=1.48 3=1.5		

Note: Values in the same column (a, b, c) and row (p, q, r) followed by the same letter indicate insignificant difference according to DMRT (P<0.05)

Table 3. The interaction effect of hydroponic substrate and LOF on the lettuce dry weight at 34 DAP according to DMRT (P<0.05)

	Rates of LOF (ml/l water)		
	0 (F_0)	5 (F_1)	10 (F_2)
RHB (M_1)	4.17 $^{q}_{b}$	4.77 $^{pq}_{b}$	5.83 $^{p}_{b}$
RHB + sand (2:1) (M_2)	6.63 $^{p}_{a}$	5.27 $^{q}_{b}$	7.70 $^{p}_{b}$
RHB + sand (1:1) (M_3)	6.37 $^{pq}_{a}$	6.70 $^{p}_{a}$	5.57 $^{q}_{b}$
DMRT α 0.05	2=1.27 3=1.34		

Note: Values in the same column (a, b, c) and row (p, q, r) followed by the same letter indicate insignificant difference according to DMRT (P<0.05)

(Soepardi, 1983) in order to achieve desired yields (Siswadi et al. 2013; Listyaningsih et al. 2014). Among others, sand, husks, and manure are to have such properties (Siswadi et al., 2012). The study showed that the soilless growing media (rice husk biochar + sand) and LOF (Moringa leaves + banana corm + coconut water + brown sugar) significantly improved the growth of lettuce (e.g. the number of leaves, and the plant fresh and dry weight), and the best growth was found when the plant was grown in the RHB+ sand media at a ratio of 2:1 (w/w) and treated with 10 ml LOF/l water (Table 1-3). This indicates that the use of the growing media at that ratio and the application of LOF at that rate are thought to be able to provide an ideal root growing conditions and provide sufficient amount of plant nutrients (Hindrawati, 2006). At a ratio of 2:1, RHB and sand compensated each other best. RHB has a high water holding capacity (Lingga, 2006) and a high organic-C content (15.23%) that could play a significant role in improving the medium aeration and drainage (Nurbaity et al. 2009). Istiqomah (2007) reported that RHB comprises of 52% SiO_2, 31 % C, and other essential elements, such as Fe_2O_3, K_2O, MgO, CaO, MnO and Cu, and has a high CEC (Wuryaningsih, 1997). Sand also has good aeration and drainage, and a high capillarity property. LOF, on the other hand, was given mainly to supply nutrients required by the plants. The findings of this study indicate that the application of the tested LOF at 10 ml/l water could provide sufficient nutrients to the plants (Duaja, 2012). Kusumaningwati (2015) reported that LOF made of Moringa leaves, banana corm, coconut water, and brown sugar had a pH of 8.59, and contained N-total 1.78%; P_2O_5 0.41% and K_2O 1.59%, so the amount of nutrients given to plants shows a better effect on the growth and development of lettuce plants. Indrawati et al. (2012) reported that the growth and yield of tomato plants are highly dependent on the media composition and hydroponic nutrient content. Nutrient solution of 210 mg N/L was 88.8 g and 96.1 g for two lettuce cultivars (Li et al., 2018) However, the fresh weight reported by Kowalczyk et al. (2014) in a nutrient solution of N, P, K of 140, 50, and 300 mg/L, respectively, was 245 g and 175 g for two other lettuce cultivars. Furthermore, the increasing N concentration on a hydroponic culture of lettuce from 0 to 60 mg/L increased shoot weight from 68.7 to 129.7 g.

Conclussios

Based on the results of the study it can be concluded that the combination of rice husk biochar and sand as a hydroponic substrate and the application of liquid organic fertilizer (LOF) of Moringa leaves and banana corm can increase the growth and production of lettuce plants. The best response of lettuce plants was found when rice husk biochar and sand were used as a growing medium at a ratio of 2: 1 (w/w) and 10 ml / l water of Moringa leaves and banana corm-derived LOF was given.

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