EFFECTS OF ORGANIC COMPOST DOSES AND REGULATED IRRIGATION ON GROWTH AND YIELD OF ORGANIC RED RAPID LETTUCE (LACTUCA SATIVA L VAR. RED RAPIDS)

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Procedia
Environmental Science, Engineering and Management
http://www.procedia-esem.eu

Procedia Environmental Science, Engineering and Management **8** (2021) (2) 397-406

Environmental Innovations: Advances in Engineering, Technology and Management, EIAETM, 19th-23rd October, 2020

EFFECTS OF ORGANIC COMPOST DOSES AND REGULATED IRRIGATION ON GROWTH AND YIELD OF ORGANIC RED RAPID LETTUCE (*LACTUCA SATIVA L VAR. RED RAPIDS*)*

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Abstract

Organic vegetables have gotten an increasing interest, but organic fertilizers and irrigation water used to produce them could be significant issues of economic calculation to be considered for some locations. This study was aimed to determine the optimum doses of organic compost and irrigation level for growing organic red lettuce in a greenhouse. Completely Random Design (CRD) coupled with factorial arrangement was implemented in this study. Treatments consisted of two factors; doses of organic compost (D) and regulated irrigation levels (I). The factor of doses included 0% (D0), 10% (D1), 30% (D2), and 50% (D3) organic compost of the total weight of the growth media (3 kg per pot). The factor of regulated irrigation levels included 40% (I1), 70% (I2), and 100% (I3) of available water. Three replicates were used, making total of 36 experimental units. The result showed that interaction effect between organic compost doses and irrigation levels on the growth, yield, and water productivity of the red rapid lettuce was significant at $\alpha = 0.05$. However, the treatments were not significant on some chemical properties of the rapid red lettuce. The most optimum scheme was found to be the treatment combination between the organic compost dose of 300 g plant^{-1} (D1) and the regulated irrigation level at 100% (I3) of available water.

Keywords: greenhouse, organic vegetable, water scarcity, water management

1. Introduction

Organic vegetables have gotten increasing public perceptions as clean, healthy, and hazardous chemical free produces. Organic vegetables refer to those, which are cultivated

* Selection and peer-review under responsibility of the EIAETM
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without the uses of chemical fertilizers and pesticides. The consumption of the fresh organic vegetables is perceived to be able to enhance the prevention of some of the health hazards associated with the consumption of conventional vegetables. This perception has encouraged consumers to consume organic vegetables even though they have to pay more. The more income households earn, and the more consumers perceive a potential negative impact on health from pesticides usage, the more likely they would be willing to pay a premium for fresh organic produces.

Lettuce (*Lactuca sativa L*), has been known as originated from Eastern Mediterranean. Lettuce is one of the vegetables that is widely cultivated organically. Red rapid Lettuce (*Lactuca sativa L var. red rapids*) is one of leafy lettuces that is preferred and consumed in raw mostly as an ingredient of salads. One reason is that red rapid lettuce contains a lot of vitamins, minerals, anti-oxidant compounds, with exceptional abundance of anthocyanins (Baslam et al., 2013), in addition to its tasty flavour.

One major problem associated with organic farming is that the system requires a lot of organic fertilizers or composts. In addition to the huge volume, cost for purchasing compost is not cheap especially for small-scale farmers in many locations. Therefore, the uses of organic composts need to be calculated wisely when developing organic vegetable cultivations. Otherwise, the organic vegetable business becomes economically unfeasible and farmers may suffer losses, resulting in slow development of organic farming systems. Current researches were mostly to determine optimum doses and types of the organic composts ((Reis et al., 2014). However, none of research studies was conducted on rapid red lettuce. Other major problem associated with organic farming is that this system needs to be supplied with adequate irrigation water, just like other general farming systems (Rosadi et al., 2019). Inadequate irrigation water may result in low yields, and eventually growers could suffer severe losses. (Chal and Yohannes, 2015) applied full drip irrigation at 100% of water requirement and produced maximum yield of green lettuce.

The above researches mentioned were all about optimizations of fertilizers (either organic or inorganic) and irrigation water for head and or for green leafy lettuces. None of the research studies above investigated organic compost and irrigation water applications on rapid red lettuce. This study aims to optimize the dose of an organic compost and irrigation level applied for organic “red rapid” lettuce cultivation.

The main objectives of this research are to evaluate the effect of organic fertilizer and irrigation on red lettuce. In addition, the objective is to determine optimum dose of an organic compost and optimum amount of irrigation water applied for organic “red rapid” lettuce cultivation in pot experiment carried out in a green house.

2. Material and methods

2.1. Site and environment

This work was conducted from June to August 2018, in a greenhouse at the Integrated Field Experimental Station, the University of Lampung, Indonesia located at 5°25’46” South Latitude and 105°15’45” East Longitude, and 150 m above see level. The average of daily maximum temperature was 32.86°C, while the average of daily minimum temperature was 25.20°C. The average of daily maximum RH was 85.43%, while the average of daily minimum RH was 62.20%. Minimum RH normally takes place at day light and maximum RH at night. The quite high temperature and low RH may not ideal for cultivation of lettuces. However, regardless of the yield, the rapid red lettuce, besides green lettuce, was grown by farmers at that location.

2.2. Medium and organic compost preparation

The properties of organic compost, soil, and plant biomass were analyzed at the Laboratory of Soil Sciences at the University of Lampung. Organic fertilizer was made from agricultural wastes which comprised of cattle manure, chicken litter, rice husk charcoal, MSG industry wastewater sludge, coconut dust, spent mushroom substrate (SMS). All materials were collected from locally available sources, but the SMS made of oil palm empty fruit bunch (OPEFB), was taken from the research facility (Triyono et al., 2019). Some properties of the raw materials and their proportion in the organic fertilizer are presented on Table 1.

Table 1. Some properties of raw materials and their proportions in the made up organic compost (%)

Compost Materials	*C*	*N*	*P*	*K*	*Water Content*	*Proportion (V/V)*
Cattle manure	22.71	1.47	1.93	1.16	54.7	30
Chicken manure	22.43	2.26	0.54	0.46	14.4	5
Rice husk Charcoal	51.30	-	-	-	3.2	5
MSG industry wastewater sludge	-	-	21.74	-	59.0	5
Coconut dust	44.67	0.56	0.27	0.72	80.6	5
Spent Mushroom Substrate	46.67	1.29	0.14	2.50	41.6	50

The material proportion of the compost was made on the basis of availability of the resources. The use of spent mushroom substrate was prioritized in order to get some economical value enhancement of locally abundant OPEFB, or otherwise the waste was left unmanaged which potentially degrades the environment quality (Haryanto et al., 2019; Hasanudin et al., 2015). The properties of the organic fertilizer resulted and the soil used in this study is presented on Table 2.

Table 2. Chemical properties of the soil and the organic fertilizer used for the growth media

Chemical Content	*Soil Medium*	*Organic Compost*
C-Org (%)	0.29	15.11
N (%)	0.04	1.27
P-Available (%)	0.85	3.02
K-dd (me/100g)	0.78	0.42

Thirty six plastic pots (27 cm upper part diameter and 20 cm height) were prepared for plating in this experiment. Each pot was filled with 3 kg mixtures of air dried soil (yellow red podzolik: sand 26.71%, silt 21.67%, clay 51.62%) and organic fertilizer, the composition of which was assigned according to the treatments. Moisture contents of the air dried media were determined by gravimetric method. Before treatment implementation, field capacities of the media were determined by saturating every pot of the media, and then drained for 24 hours. The field capacities of the media were considered being reached when the water stopped dripping. Permanent wilting point was determined by using the ratio of field capacity to wilting point by 1.75:1 (Phocaides, 2007). Available water was defined by field capacity minus permanent wilting point.

2.3. Seedling and transplanting preparation

Each seed of Red Rapid variety was inserted on the top part of a 2.5x2.5x3.5 cm^3 rock wool medium, and placed on a tray. The seedlings were watered regularly to maintain moisture until they have developed two true leaves. At the 21^{st} day after sowing, the sprouts of equal heights were selected and transplanted into the prepared plastic pots and were cultivated in a green house which was roofed with 14% UV plastic and protected with 50 mesh insect screen.

2.4. Experimental Design and Analysis, Parameter measurements

Completely Randomized Design (CRD) coupled with factorial arrangement was implemented in this study. Treatments consisted of two factors; doses of organic fertilizer (D) and regulated irrigation levels (I). The factor of doses included 0% (D0), 10% (D1), 30% (D2), and 50% (D3) organic compost based on total weight of the media (3 kg per pot). The factor of regulated irrigation levels included 40% (I1), 70% (I2), and 100% (I3) of available water. Three replicates were used, making total of 36 experimental units. The data set was analyzed by using Analysis of Variance (ANOVA) and followed by least significant differences (LSD).

Moisture contents of the media were monitored by weighing the pots of the media twice a day, in the morning and on the afternoon. Water lost due to evapotranspiration was replaced by irrigating the plants, to the assigned weight corresponding to the treatment of the irrigation levels. Parameters observed daily included plant growth (ruler), stem diameter (caliber), number of leaves, canopy area (vertical photograph), and water consumption (gravity/weighing). Parameters measured at harvest day included yield (weighing), NPK contents of plants (standard laboratory protocols), compost productivity, and water productivity.

3. Results and discussion

3.1. Plant growth

The effects of organic fertilizer doses (D) and regulated irrigation (I) on plant height at the end season is graphically presented on Fig. 1. The interaction effect between organic fertilizer doses (D) and irrigation levels (I) on the plant height was significant at $\alpha < 0.01$. Even the responses were different; all the plant height increases with organic fertilizer doses were noticeable. At all the irrigation levels (I1, I2 and I3), the plant height responses fitted on quadratic models. But as we can see on Fig. 1, plant heights at I1 were lower as compared to I2 and I3. Plan heights of D2I3 (32.83 cm) and D3I3 (34.13 cm) were found to be the best two. These plant heights were taller that those (12-23 cm) of red lettuce reported by (Masarirambi et al., 2010).

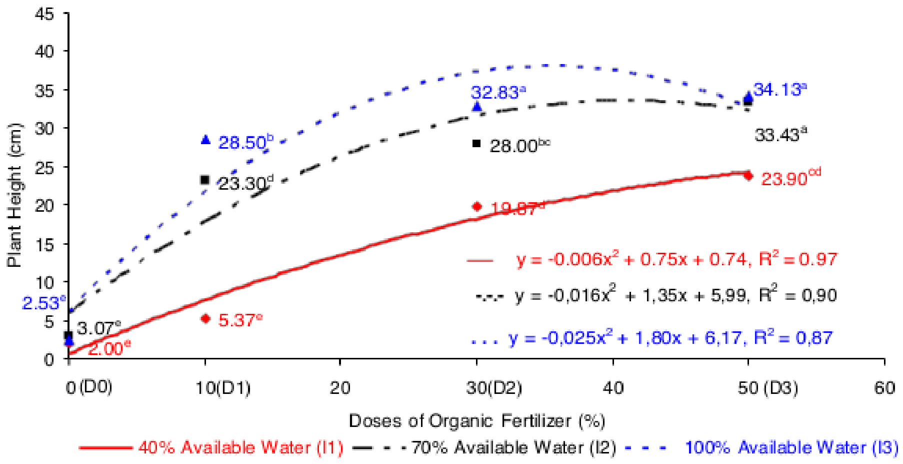

Fig. 1. Effect of interaction between organic fertilizer doses and irrigation levels on plant height at the end season. Note: Means with the same letter are not significantly different at $\alpha < 0.01$

The effects of organic fertilizer doses (D) and regulated irrigation (I) on number of leaves at the end season is graphically presented on Fig. 2. The interaction effect between organic fertilizer doses (D) and irrigation levels (I) on number of leaves was significant at $\alpha < 0.05$. Even the responses were different; all numbers of leaves were observed to increase with organic fertilizer doses. At the irrigation level of I_1, the number of leaves response fitted on linear model (R^2=0.91). While at the irrigation levels of I_2 and I_3, the number of leaves responses fitted on the quadratic models (R^2=0.86 and R^2=0.81 respectively). But as we can see on Fig. 2, number of leaves at irrigation level of I_1 was lower as compared to those at the irrigation levels of I_2 and I_3. The numbers of leaves of D_3I_2 (16.67 plant^{-1}) and of D_3I_3 (15.33 plant^{-1}) turned out to be the highest numbers. the best numbers of leaves were comparable to those (9-16 plant^{-1}) of red lettuce reported by (Masarirambi et al., 2010).

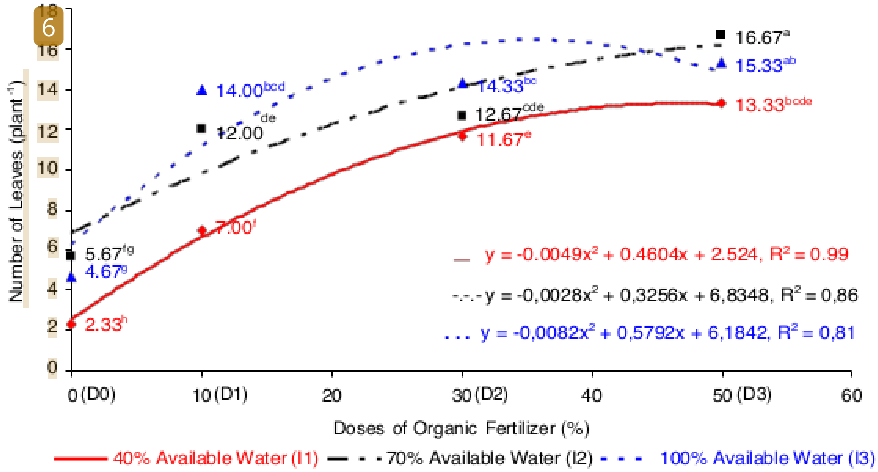

Fig. 2. Effect of Interaction between organic fertilizer doses and irrigation levels on number of leaves at the end season. Note: Means with the same letter are not significantly different at $\alpha = 0.01$

The effects of organic fertilizer doses (D) and regulated irrigation (I) on stem diameter at the end season is graphically presented on Fig. 3.

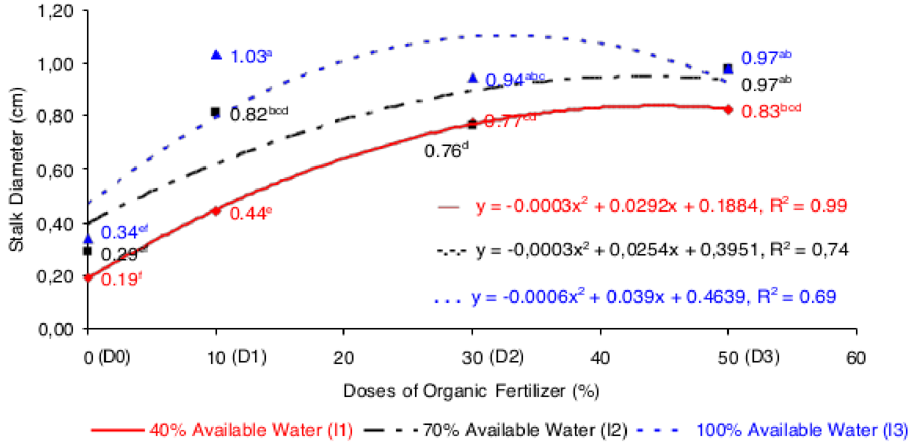

Fig. 3. Effect of Interaction between organic fertilizer doses and irrigation levels on stem diameter at the end season Note: Means with the same letter are not significantly different at $\alpha = 0.01$

The interaction effect between organic fertilizer doses (D) and irrigation levels (I) on the stem diameter was not significant at $\alpha < 0.05$. However; both the simple effects of organic fertilizer doses (D) and irrigation levels (I) on the stem diameters are each significant at $\alpha < 0.01$. Even the responses were different; all stem diameters were observed to increase with organic fertilizer doses, fitting quadratic models with R squares of 0.99, 0.74, and 0.69 respectively for I1, I2, and I3. However, the stem diameters at D1I3 (1.03 cm), D2I3 (0.94 cm), D3I2 (0.97 cm), and D3I3 (0.97 cm) turned out to be the best four among the others.

The effects of organic fertilizer doses (D) and regulated irrigation (I) on canopy area at the end season is graphically presented on Fig. 4. The interaction effect between organic fertilizer doses (D) and irrigation levels (I) on the stem diameter was significant at $\alpha < 0.01$. Both the simple effects of organic fertilizer doses (D) and irrigation levels (I) on the canopy area were significant at $\alpha < 0.01$ too. All canopy areas were noticeable to increase with organic fertilizer doses, and could be fitted on quadratic models with R squares of 0.98, 0.89, and 0.84 respectively for I1, I2, and I3. The canopy areas at D1I3 (564.34 cm^2), D2I3 (610.03 cm^2), D3I2 (730.16 cm^2), and D3I3 (588.50 cm^2) turned out to be the best four among the treatment combinations. These canopy areas were comparable to those of green lettuce (580.43-725.87 cm^2) reported by (Peiris and Weerakkody, 2015).

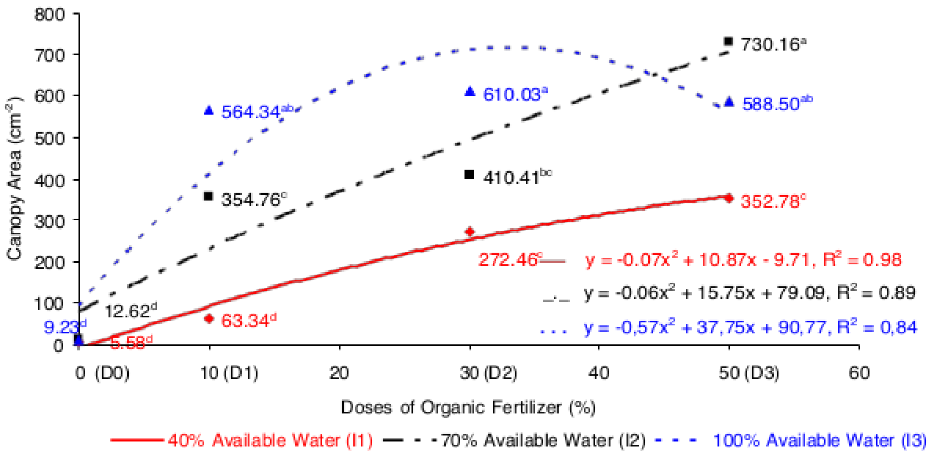

Fig. 4. Effect of Interaction between organic fertilizer doses and irrigation levels on canopy area

3.2. Yield and water productivity

The effects of organic fertilizer doses (D) and regulated irrigation (I) on shoot fresh weight harvested is graphically presented on Fig. 5. The interaction effect between organic fertilizer doses (D) and irrigation levels (I) on the shoot fresh weight was significant at $\alpha = 0.01$. Both the simple effects of organic fertilizer doses (D) and irrigation levels (I) on the shoot fresh weight were significant at $\alpha = 0.01$ too. All the shoot fresh weight parameters were observable to increase with organic fertilizer doses, and could be fitted on quadratic models with R^2 of 0.97, 0.92, and 0.80 respectively for I1, I2, and I3. The shoot fresh weight parameters at D1I3 (62.07g $plant^{-1}$), D2I3 (63,96 g $plant^{-1}$), D3I2 (61,28 g $plant^{-1}$), and D3I3 (64,99 g $plant^{-1}$) turned out to be the best four among all the treatment combinations. These highest shoot fresh weights were better than those of green lettuce (33.13-45.4 g $plant^{-1}$) reported by (Peiris and Weerakkody, 2015).

The effects of organic fertilizer doses (D) and regulated irrigation (I) on total water consumption along the growing season is graphically presented on Fig 6. The interaction effect between organic fertilizer doses (D) and irrigation levels (I) on the total water consumption was not significant at α = 0.05. However; both the simple effects of organic fertilizer doses (D) and irrigation levels (I) on the total water consumption were significant at α < 0.01. All the total water consumptions were observable to increase with organic fertilizer doses, and could be fitted on quadratic models with R squares of 0.99, 0.99, and 0.81 respectively for I1, I2, and I3. The total water consumptions at D1I3 (5689.00mL), D2I3 (5693.00mL), and D3I3 (6298.00mL) turned out to be the highest among all the treatment combinations.

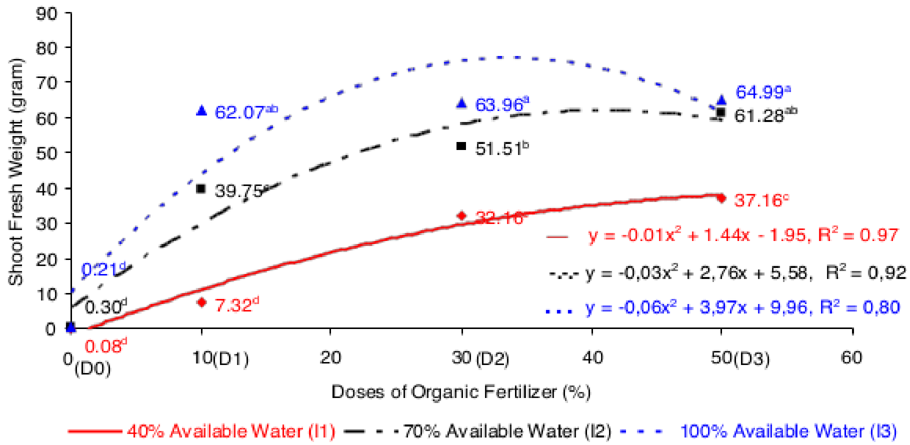

Fig. 5. Effect of Interaction between organic fertilizer doses and irrigation levels on shoot fresh weight. Means with the same letter are not significantly different at α = 0.01

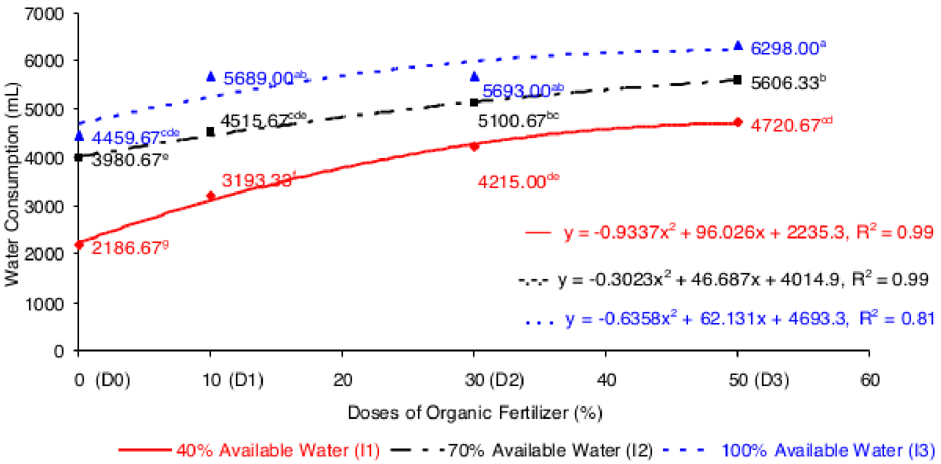

Fig. 6. Effect of Interaction between organic fertilizer doses and irrigation levels on total water consumption. Note: Means with the same letter are not significantly different at α = 0.01

The effects of organic fertilizer doses (D) and regulated irrigation (I) on water productivity is graphically presented on Fig. 7. The water productivity here is defined as the shoot fresh weight harvested over the amount of irrigation water applied. This parameter could be very important particularly when water is limited. The interaction effect between organic fertilizer doses (D) and irrigation levels (I) on the water productivity was very significant at α = 0.01. Both the simple effects of organic fertilizer doses (D) and irrigation levels (I) on the water productivity were very significant at α = 0.01 too. Responses of the water productivity to the organic fertilizer doses were different among the irrigation levels. But, the responses of the water productivity fitted on quadratic models with R^2 of 0.98, 0.87, and 0.87 each for I1, I2, and I3. The highest water productivities fell into D1I3 (10.91 kg. m^{-3}), D2I2 (10.10 kg.m^{-3}), D2I3 (11.24 kg.m^{-3}), D3I2 (10.93 kg.m^{-3}), and D3I3 (10.32 kg.m^{-3}).

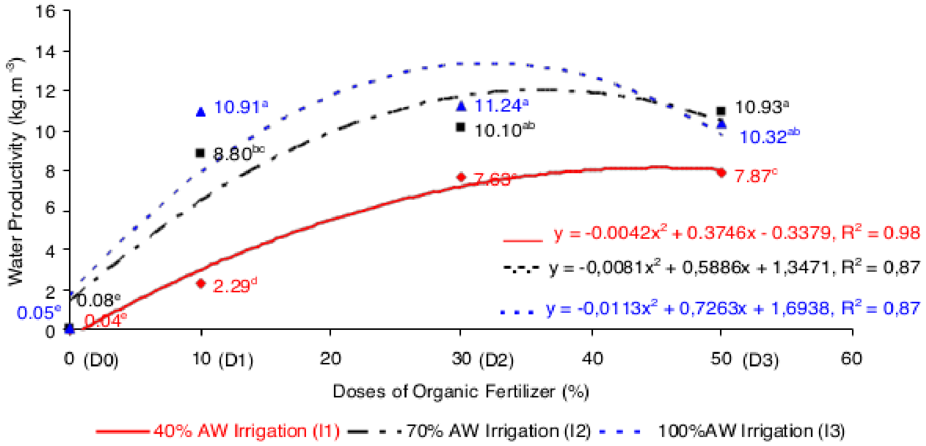

Fig. 7. Effect of interaction between organic fertilizer doses and irrigation levels on water productivity. Means with the same letter are not significantly different at α = 0.01

3.3. Some chemical properties of Plants

The some chemical property of the red rapid lettuce is presented on Table 3. Sample of control (D0) was not incorporated in the analyses because the biomass of the plans was too small and not enough for the chemical property analyses. Statistical analyses showed that none of the interaction effects on the some chemical properties (C, N, P, K) of the plants was significant at $\alpha = 0.05$. Based on these chemical properties, we can conclude that the qualities of red rapid lettuce grown on the different medium fertility were not different. The averages were 34.67%, 3.34%, 0.47%, and 4.60% respectively for organic C, N, P, and K. Although not significantly different, these chemical contents were still better than that (1.14-2.24%) of green lettuce reported by (Reis et al., 2014).

Table 3. Effect of interaction between organic fertilizer doses and irrigation levels on some chemical properties of the red rapid lettuce

NO	*Treatment Combinations*	*Chemical Contents (%)*			
		C- Organic	*N*	*P*	*K*
1	D1I1	34.41	3.39	0.22	4.43
2	D1I2	35.21	3.20	0.23	4.11
3	D1I3	34.08	3.29	0.38	4.43
4	D2I1	35.70	3.33	0.55	4.77
5	D2I2	35.02	3.62	0.59	4.61
6	D2I3	34.77	3.09	0.45	4.93
7	D1I1	34.65	3.46	0.63	4.67
8	D1I2	34.21	3.34	0.63	4.71
9	D1I3	33.96	3.31	0.51	4.76
	Averages	34.67	3.34	0.47	4.60

Even though chemical contents were not significantly different among the treatment combinations, optimum schemes of red rapid lettuce cultivation needed to be determined, based on every parameter summarized on Table 4. The selection should be based on maximum marketable yield (shoot fresh weight) and optimum resources used. Table 4 shows that the optimum choices should be on D1T3 (organic fertilizer dose of 10% or 300 g plant^{-1} combined with regulated irrigation level at 100% of available water). The scheme of D1T3 is the best in terms of both shoot fresh weight and water productivity parameters. There is no need to increase organic fertilizer dose (such as D2T3 and D3T3) because it will not improve both of yield and water productivity. In the contrary, if the regulated irrigation level is decreased, the yield will significantly decrease. This choice is reasonable particularly for locations where organic fertilizer is considerably expensive and irrigation water is not limited.

Table 4. Summary of best treatment combinations

No	*Parameters*	*Unit*	*Best Treatment Combinations*
1	Plant height	cm	D2I3, D3I3
2	Number of leaves	Plant^{-1}	D3I2, D3I3
3	Stem diameter	cm	D1I3, D2I3, D3I2, D3I3
4	Canopy area	cm^2	D1I3, D2I3, D3I2, D3I3
5	Shoot fresh weight	g plant^{-1}	D1I3, D2I3, D3I2, D3I3
6	Water consumption	mL plant^{-1}	D1I3, D2I3, D3I3
7	Water productivity	kg m^{-3}	D1I3, D2I2, D2I3, D3I2, D3I3
8	Chemical property of plant (C, N, P, K contents)	%	none

The treatment combination of D3I2 (organic fertilizer dose of 50% or 1500 g plant^{-1} combined with irrigation level at 70% of available water) may be selected as the other option with the consequence of increasing organic fertilizer dose (1500 kg plant^{-1}) used but with lower amount of irrigation water (70% of available water). This kind of option may be applicable for locations where organic fertilizers are not expensive and irrigation water is limited.

The treatment of D2I2 (organic fertilizer dose of 30%or 1000 g plant^{-1} combined with irrigation level at 70% of available water) may be selected as another alternative in that it has the highest water productivity too. As consequent, the yield will significantly decrease by about 19.47%. The treatment of D2I2 is not one of the best treatments in term of shoot fresh weight. The advantage of D2I2 is that it consumed little amount of irrigation water. But its disadvantage is that it needed more organic fertilizer dose as compared to D1I3. Therefore; the treatment of D2I2 may be suitable for any locations where organic fertilizer is not expensive and irrigation water is limited.

The treatment of D1I3 was not included in the best treatments based on the parameters of plant height and number of leaves. It should not be a problem as far as leafy lettuce is priced for its weight. Furthermore; lettuce height could be stimulated by bolting process when atmospheric temperature is too hot or etiolating when the weather is cloudy for a particular period of time. The number of leaves is not the determining parameter either because large area of leaves could have heavier weight even the number is fewer. At last, chemical property in term of C, N, P, K contents is not the determining parameter for the optimum scheme selection in this study.

4. Conclusions

The interaction effect between doses of organic fertilizer and irrigation levels on the growth, yield, and water productivity of the red rapid lettuce was significant for some parameters. However, the treatments were not significant on some chemical properties of the rapid red lettuce. The most optimum scheme is the treatment combination between the organic compost dose of 300 g $plant^{-1}$ and the irrigation level at 100% of available water. The yield (shoot fresh weight) of the optimum scheme was 62.07g $plant^{-1}$.

Acknowledgements

Great appreciation is delivered to the Indonesian Ministry of Research, Technology and Higher Education for the support of funding this research.

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