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Effects of water flow rate and surface cover plant density on the growth of duckweed (*Lemna minor* L.)

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ABSTRACT

Globally, agriculture sector is facing unprecedented challenges in producing fertilizers and increasing the amount of fertilizer production without having negative impact on the environment. Thus, the organic fertilizers are needed to be produced as they do not give any damages to the environment. Duckweed plant has a lot of potentials that can be used in the agriculture sector. This plant can breed in approximately 16–48 hours by splitting. The water needs and its breeding speed ability are the basis for conducting this research. The research objective was to determine the effect of water flow rate and surface cover plant density on the growth and yield of duckweed plants. This research was conducted in November–December 2018 in Cangkringan District, Sleman, Special Region of Yogyakarta, Indonesia. The experiment was arranged in a split plot design. The main plot was irrigation water flow rate, consisting of two levels, namely large water flow rate (0.336 $L.second^{-1}$) and small water flow rate (0.085 $L.second^{-1}$). The subplot was the density of the duckweed plant surface cover, consisting of 10%, 20%, 40% and 60%. The results of this study indicated there was no effect of water flow rate on the plant growth, yield, and yield quality of duckweed plants. The C/N ratio of the duckweed plants fulfilled the requirement to be used as green manure.

INTRODUCTION

In Indonesia, duckweed is cultivated in the rice fields or growing naturally in open water (aquatic habitat). Duckweed is a common name for *Lemna minor* L., included in the genus of Lemna, a genus of free-floating aquatic plants (United States Department of Agriculture, 2015). Duckweed has a very wide spread, more considered as weed in the water that tend to be difficult to control (Said, 2006). However, duckweed has high content of nutrient, especially protein content, and can be used as fertilizer, as stated by Skillicorn et al. (1993) that duckweed has high concentrations of minerals and pigments, especially beta carotene and xanthophyll. According to Landolt and Kandeler (1987), duckweed contains N and P of 0.8–7.8% and 0.03–2.8% of the total dry weight, respectively, and also some other nutrients. Duckweed plants must be bred in the condition of water that continues to flow as these plants need oxygen so that they need water circulation to maintain the temperature in the water. They can grow at the temperature of 5–35°C with an optimal temperature of 26°C (Ruigrok, 2015). Duckweed plants require enough oxygen and the optimal temperature to grow properly. The water flow rate will affect the oxygen distribution and temperature stability, as stated by Van Den Top (2014) and Ruigrok (2015) that duckweed plant will die after experiencing a lack of oxygen and exposed to high temperature. In general, duckweed plant will die when the air temperature reaches 47°C, and the water temperature reaches more than 40°C. Data from ecoferm model in 2015 in the Netherlands showed that a routine duckweed harvesting decreased in the second week of June as a lot of duckweed died due to high temperatures and low oxygen level. The temperature affects the chemical and physical processes of duckweed plants, such as nutrient absorption, assimilation and nutrient translocation, photosynthesis, respiration, diffusion, water flow, and other various enzymatic activities. Duckweed plants can also accumulate and assimilate pollutants from water (Sekomo et al., 2012) so that they can purify the water from various types of pollutants. This study aimed to determine the effect of water flow rate and surface cover plant density on the growth and yield of duckweed.

MATERIALS AND METHODS

This research was conducted in the paddy fields of local farmers located in Cangkringan, Sleman Regency, Special Region of Yogyakarta, Indonesia from November to December 2018. The research was arranged in a split plot design. The main plot was the rate of water flowing to the pond in which the duckweed plants were grown, consisting of two levels, which were a big flow rate (0.336 $L.second^{-1}$) and small flow rate (0.085 $L.second^{-1}$). Meanwhile, the subplot was the surface cover plant density, consisting of 10%, 20%, 40% and 60%. The size of the main plot was 4 × 2 × 0.3 m, and that of the sub plot was 1 × 2 × 0.3 m.

Duckweed plants (*L. minor* L.) and other laboratory materials for laboratory analysis, such as aquadest, 80% acetone, 0.1 M phosphate buffer pH 7, 5 M $NaNO_3$, 1% sulfanilamide (SA) solution, HCl and N-Naphthyl Ethylene Diamin solution (NED) 0.02%, H_2SO_4, H_2O_2, manganese sulfate ($MnSO_4$) solution, alkaline iodide solution (oxygen reaction), concentrated sulfuric acid (H_2SO_4), standard solution of sodium thiosulfate ($Na_2S_2O_3$) 0.01N, and starch indicator solution were used in this study. Data were analyzed using ANOVA followed by Duncan's Multiple Range Test (DMRT) test at α=5%. The equipment used in this study were gauze, wood beam, wooden frame with a size of 25 × 25 cm, hoe, pipe, meter, stationery, sorong wood, hammer, scissors, nails, saws, BWD board, lux meter, EC meter , EC meter, camera, scales, oven, sieves, pH meter, measuring pipette, titration pipette, drop pipette, Winkler bottle, Erlenmeyer tube, filter paper, test tube, measuring cup, spektronik -21D, spectra λ889 nm/693 nm, thermohygrometer, funnel, Burette 50 ml, 2 ml measuring pipette and suction ball, Winkler/DO bottle, 250 ml Erlenmeyer flask, 100 ml volume pipette, and spray bottle.

The variables observed were the Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolve Oxygen (DO), nitrate reductase activity (μmol $NO_2.g^{-1}$ per hour), chlorophyll content ($mg.g^{-1}$), N content, and C/N ratio, which were measured using analysis in laboratory. Besides, the measurement was also made on the leaf color (leaf color chart), leaf area ratio ($dm^2.g^{-1}$), leaf area index, net assimilation rate ($g.dm^{-2}$ per week), and plant relative growth rate ($g.g^{-1}$ per week). The fresh weight (g) and dry weight (g) of the plant were measured using analytical scales.

RESULTS AND DISCUSSIONS

Data on soil nutrient content and microclimate of the research location can be seen in Table 1 and Table 2. Data on macronutrient content was obtained from secondary data of AIAT (Assessment Institute for Agricultural Technology) Yogyakarta in 2018.

The nutrient content is relatively low in young volcanic soil (Regosol). As stated by Foth and Ellis (1988), a very young volcanic soil (volcanic regosols; entisols) contains the least nutrient content as the soil fraction is dominated by a sand fraction, which means that nutrients are not widely available in the soil.

The microclimate data of the research location was obtained through the measurements using a certain tool when the sampling was done at the research location. The measurements were carried out between afternoon until before the evening. The temperature was not too high (below the average of 30°C) as the location of the research location is at the foot of Mount Merapi. Meanwhile, the low light intensity observed was due to the location area that is often covered by clouds so it was shady. The percentage of humidity was high with an average of 77% due to low light intensity resulting in no evaporation, besides, the study was conducted during was the rainy season, which might result in the high humidity.

The result showed that both the water flow rate and/or surface cover plant density gave no significant effect on the BOD, COD and DO value of water

Table 1. Macronutrient element content in the soil in Wukirsari

Nutrient	Nutrient percentage (%)
Organic matters (plants and animals)	0.88
N	0.10
P	0.73
K	3.52
S	0.50
Mg	0.34
Ca	9.17

Source : Assessment Institute for Agricultural Technology (AIAT) Yogyakarta 2018

Table 2. Microclimate data in Wukirsari

Observation	Microclimate		
	Temperature (°C)	Light intensity (Lux)	Humidity (%)
1st Week	25.2	284	69
3rd Week	29.5	329	86
5th Week	27.3	222	77
Average	27.3	278.3	77.3

Table 3. The Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolve Oxygen (DO) (mg.L^{-1}) of water at 1 and 5 WAP

Treatments	1 WAP			5 WAP		
	BOD	COD*	DO	BOD*	COD*	DO
Water flow rate (L.second^{-1})						
0.085	1.8 p	11.7 p	6.3 p	6.3 p	58.3 p	6.1 p
0.336	2.0 p	11.0 p	6.5 p	4.7 p	39.6 p	6.8 p
Surface cover plant density						
10%	2.1 a	9.5 a	6.3 a	5.8 a	52.7 a	7.0 a
20%	2.0 a	12.5 a	6.4 a	5.4 a	50.3 a	6.3 a
40%	1.8 a	14.1 a	6.5 a	5.6 a	50.6 a	6.3 a
60%	2.0 a	11.0 a	6.3 a	5.1 a	42.2 a	6.4 a
Interaction	(-)	(-)	(-)	(-)	(-)	(-)
CV (%)	19.68	17.18	6.87	8.42	10.40	10.27

Remarks: Means followed by the same letters in the same column were not significantly different based on DMRT at α = 5%. The (-) sign shows no interaction between factors. The (*) sign indicates data were transformed using a formula of $\sqrt{(x+0.5)}$; WAP: Week After Planting

(Table 3). The BOD value of water treated either with small or large flow rate and covered with duckweed plants at a density of 10 % or closed up to 60 % turned out to have no different result. In addition, the source of water used to irrigate ponds comes from the same source, which is canal irrigation from the mountain spring, containing low organic matter. Boyd (2009) states that the BOD is a parameter to see oxygen depletion in the water, which can be defined as the amount of oxygen needed by microbes to decompose organic matter within a certain period of time. A good BOD value is below of 10 mg.L^{-1}.

COD value at 5 WAP was higher than that at 1 WAP, which was above 40 mg.L^{-1}. This result is because at 5 WAP, the age of the paddy was more mature, and the fertilizer had been applied to the paddy so that more fertilizer was leached along with the water flowing to the experimental pond. This result is supported by Zhang et al. (2017) who state that COD is a process to reduce substances that require oxidation in the water using chemical methods.

Water flow rate and surface cover of plant density also did not affected the value of DO in the water of experimental pond from 1–5 WAP (Table 3). This result was due to the flow of water used to irrigate the pond was from the same source, and a lot of oxygen was used to decompose existing organic matter and oxidize substances in the pond. A good DO value for living things in water is at least 5 mg.L^{-1}. The amount of dissolved oxygen in water can increase through floating small water plants and phytoplankton (Chesapeake Bay, 2002).

The water flow rate gave no significant effect on the variables observed (Table 4), but there were siginificant efect in the density of the duckweed plant surface cover. At the beginning of the growth, duckweed did not develop rapidly, thus, as the density of the duckweed plant surface cover got higher, the water temperature tended to be lower. However, at 5 WAP, when the duckweed plant had developed quite rapidly, there was no significant difference in water temperature among all the surface cover plant densities.

The density and thickness of the duckweed plants significantly affected the water temperature. The thicker the plants cover, the lower the water temperature, as the sun is not able to penetrate the layer of plants at the surface of the water. However, the average water temperature increased at 5 WAP as the plant layer was too thick so the plants absorbed all the heat on the surface of the water, and most of the plants died. In the end of observation, the plant population decreased and it couldn't cover whole surfaces. According to Rooijakkers (2016), duckweed plants can grow at the temperature range of 5–35°C. Sooner or later, a chemical and physical process in the body of the duckweed plant is strongly influenced by the temperature (Landolt and Kandeler, 1987).

Table 4. Water temperature (°C) at 1, 3, and 5 WAP

Treatments	1 WAP	3 WAP	5 WAP
Water flow rate (L.$second^{-1}$)			
0.085	29.4 p	29.5 p	31.8 p
0.336	29.4 p	29.5 p	30.8 p
Surface cover plant density			
10%	29.6 a	30.1 a	31.0 a
20%	29.3 b	29.5 ab	30.8 a
40%	29.4 ab	29.2 b	31.8 a
60%	29.2 b	29.1 b	31.6 a
Interaction	(-)	(-)	(-)
CV (%)	0.79	2.05	3.71

Remarks: Means followed by the same letters in the same column are not significantly different based on DMRT at α = 5%. The (-) sign shows no interaction between factors. WAP: Week After Planting

Based on Table 5, the density of surface cover plant gave a not significant effect on the value of nitrate reductase activity at 1 and 5 WAP. Meanwhile, at 3 WAP, the density of surface cover plant (20% and 40%) significantly decreased the value of nitrate reductase activities as none of the duckweed plants are given organic fertilizer or N fertilizer according to insignificant duckweed growth.

The 20% of surface cover showed a significantly different result on the total of chlorophyll content at 3 WAP compared to 10% and 60% of surface cover (Table 6), but not significantly different compared to the 40% of surface cover as there was no treatment of both organic and inorganic fertilizers, such as N fertilizer, into the experimental pond to accelerate the growth of duckweed. Hasan and Chakrabarti (2009) state that the most important nutrients for duckweed plant growth are nitrogen and phosphorus. Ammonia is an element that is absorbed by duckweed plant and is used to carry out biochemical processes in the organs that produce assimilates, one of which is chlorophyll. Maisura et al. (2014) also state that

Table 5. Nitrate reductase (NR) activity (µmol $NO_2.g^{-1}$ per hour) of duckweed plants at 1, 3, and 5 WAP

Treatments	1 WAP*	3 WAP	5 WAP
Water flow rate ($L.second^{-1}$)			
0.085	6.052 p	7.243 p	0.941 p
0.336	9.414 p	7.195 p	0.594 p
Surface cover plant density			
10%	8.558 a	7.338 a	0.739 a
20%	7.580 a	7.054 b	0.740 a
40%	6.847 a	7.112 ab	0.734 a
60%	7.947 a	7.372 a	0.858 a
Interaction	(-)	(-)	(-)
CV (%)	9.99	2.98	18.81

Remarks: Means followed by the same letters in the same column were not significantly different based on DMRT at 5%. The (-) sign shows no interaction between factors. The (*) sign indicates data were transformed using a formula of $\sqrt{(x+0.5)}$; WAP: Week After Planting.

Table 6. Total chlorophyll content ($mg.g^{-1}$) in duckweed leaves at 1, 3, and 5 WAP

Treatments	1 WAP*	3 WAP	5 WAP*
Water flow rate ($L.second^{-1}$)			
0.085	0.188 p	0.266 p	0.327 p
0.336	0.199 p	0.273 p	0.379 p
Surface cover plant density			
10%	0.187 a	0.252 b	0.356 a
20%	0.218 a	0.293 a	0.337 a
40%	0.179 a	0.285 ab	0.326 a
60%	0.190 a	0.247 b	0.395 a
Interaction	(-)	(-)	(-)
CV (%)	2.44	11.44	6.75

Remarks: Means followed by the same letters in the same column were not significantly different based on DMRT at 5%. The (-) sign shows no interaction between factors. The (*) sign indicates data were transformed using a formula of $\sqrt{(x+0.5)}$; WAP: Week After Planting.

chlorophyll is the main component of chloroplasts to carry out the photosynthesis.

Table 7 showed that there was no interaction effect of water flow rate and surface cover plant density on the leaf color as there was lack amount of N availability in the experimental pond. Nontji (1973) states that one of the important factors for synthesizing chlorophyll is the availability of N element. The leaf green matter can be obtained from the synthesis of chlorophyll that occurs in leaf cells that have photosynthetic pigment. Chlorophyll is inside the leaf chloroplast in which the leaf color pigments are located. Chloroplast is green in color as chlorophyll a and b absorb violet and red light (Handoko and Fajariyanti, 2013). The greener the leaf color, the higher the chlorophyll content in the plant.

Water flow rate and surface cover plant density also not significantly affected on the LAR values of duckweed plants in the 1, 3 and 5 WAP (Table 8). However, at 5 WAP, the 60% surface cover resulted in the higher LAR compared to the 40% surface cover as the number of leaves in plants at a density of 60% was higher. Sitompul and Guritno (1995) state that the leaf area ratio is one of the parameters to determine the assimilate translocation to the sites of leaf synthesis and the efficiency of substrate use in the leaf formation.

Table 7. Score of leaf color at 1, 3, and 5 WAP

Treatment	1 WAP	3 WAP	5 WAP
Water flow rate (L.second^{-1})			
0.085	2 p	2 p	2 p
0.336	2 p	2 p	2 p
Surface cover plant density			
10%	2 a	2 a	2 a
20%	2 a	2 a	2 a
40%	2 a	2 a	2 a
60%	2 a	2 a	2 a
Interaction	(-)	(-)	(-)
CV (%)	0	0	0

Remarks: Means followed by the same letters in the same column were not significantly different based on DMRT at α = 5%. The (-) sign shows no interaction between factors; WAP (Week After Planting).

Table 8. Leaf area ratio (dm^2.g^{-1}) of duckweed plants at 1, 3, and 5 WAP

Treatments	1 WAP*	3 WAP	5 WAP
Water flow rate (L.second^{-1})			
0.085	281.33 q	359.57 p	215.80 p
0.336	309.67 p	338.80 p	249.70 p
Surface cover plant density			
10%	308.71 a	290.30 a	232.77 ab
20%	314.88 a	359.68 a	232.42 ab
40%	286.08 a	378.18 a	213.78 b
60%	272.33 a	368.58 a	252.02 a
Interaction	(-)	(-)	(-)
CV (%)	9.81	11.76	10.59

Remarks: Means followed by the same letters in the same column were not significantly different based on DMRT at α = 5%. The (-) sign shows no interaction between factors. The (*) sign indicates data were transformed using a formula of √(x+0.5); WAP: Week After Planting.

Surface cover plant density significantly affected the LAI of the duckweed plants in the 1, 3 and 5 WAP (Table 9). There was a tendency that surface cover above 20% caused an increase in the LAI. Nevertheless, there was a slight deviation at 3 WAP, in which the LAI resulted by the treatment of 60% surface cover was lower compared to that resulted by the 40% surface cover, which was not significantly different from the result of the 20% surface cover. This result was due to the high population of duckweed plants at a density of 60%, which covered the entire surface of the pond. In addition, the duckweed plants also reproduced quickly so that the highest LAI value was found in the surface cover plant density of 60% cover at 1 and 5 WAP. Meanwhile, at 3 WAP, the 40% surface cover resulted in the highest LAI as most of plants died at a density of 60%. FAO (2017) state that duckweed can replicate themselves with a span of 16–48 h in ideal environmental conditions related to water temperature, light intensity, pH, and the concentration of nutrients needed by the plant.

Water flow rate and surface cover plant density did not affected the NAR value in the 1, 3 and 5 WAP (Table 10), as there was no application of nutrients nor N fertilizer into the experimental pond so that the value of chlorophyll content remained low, resulting

Table 9. Leaf area index of duckweed plants at 1, 3, and 5 WAP

Treatments	1 WAP	3 WAP*	5 WAP
Water flow rate (L.second^{-1})			
0.085	20.67 p	41.23 p	29.75 p
0.336	20.25 p	38.78 p	33.17 p
Surface cover plant density			
10%	16.33 b	33.67 b	28.83 b
20%	17.83 b	38.23 ab	29.67 b
40%	23.00 a	49.47 a	30.50 ab
60%	24.67 a	38.67 ab	36.83 a
Interaction	(-)	(-)	(-)
CV (%)	18.37	12.79	16.92

Remarks: Means followed by the same letters in the same column were not significantly different based on DMRT at α = 5%. The (-) sign shows no interaction between factors. The (*) sign indicates data were transformed using a formula of √(x+0.5); WAP: Week After Planting.

Table 10. Net assimilation rate (g.dm^{-2} per week) of duckweed plants at 1–3 WAP and 3–5 WAP

Treatment	1–3 WAP*	1–5 WAP*
Water flow rate (L.second^{-1})		
0.085	0.00110 p	0.00063 p
0.336	0.00130 p	0.00066 p
Surface cover plant density		
10%	0.00139 a	0.00076 a
20%	0.00182 a	0.00075 a
40%	0.00094 a	0.00059 a
60%	0.00066 a	0.00048 a
Interaction	(-)	(-)
CV (%)	10.79	0.03

Remarks: Means followed by the same letters in the same column were not significantly different based on DMRT at α = 5%. The (-) sign shows no interaction between factors. The (*) sign indicates data were transformed using a formula of √(x+0.5); WAP: Week After Planting.

in a low rate of plant assimilation. According to Poorter and Remkes (1990), NAR is the addition of dry weight per unit leaf area per units of time. Dry weight is obtained from the photosynthesis carried out by the plants. The chlorophyll content in the plant significantly affects the value of NAR of the plants.

Table 11 showed that there was a significant effect of the surface cover plant density observed on the RGR. At 3–5 WAP, the 10% and 20% surface cover resulted in significantly higher RGR value compared to the 40% and 60% surface cover. At 5 WAP, the duckweed plants grown at a density of 60% mostly died due to the lack of space to grow. This condition significantly affected the total plant dry weight and the RGR as well. The result of the study is supported by Sitompul and Guritno (1995), stating that the plant relative growth rate is the increase of dry weight at certain time interval, which can be used as a parameter for efficient productivity of the plant biomass.

Based on Table 12, each treatment was found to have significant effect on the fresh weight of the duckweed plants. The surface cover plant density of 40% and 60% showed a significantly higher total plant fresh weight compared to the 10% and 20% surface cover at 1 WAP. At 3 WAP, the 60% surface

Table 11. Relative growth rate ($g.m^{-2}$ per week) of duckweed plants at 1–3 WAP and 3–5 WAP

Treatments	1–3 WAP*	1–5 WAP
Water flow rate ($L.second^{-1}$)		
0.085	0.311 p	0.400 p
0.336	0.329 p	0.427 p
Surface cover plant density		
10%	0.392 a	0.482 a
20%	0.417 a	0.452 a
40%	0.285 a	0.373 b
60%	0.185 a	0.347 b
Interaction	(-)	(-)
CV (%)	0.11	14.13

Remarks: Means followed by the same letters in the same column were not significantly different based on DMRT at α = 5%. The (-) sign shows no interaction between factors. The (*) sign indicates data were transformed using a formula of √(x+0.5); WAP: Week After Planting.

Table 12. Total fresh weight (g) of duckweed plants at 1, 3, and 5 WAP

Treatments	1 WAP	3 WAP	5 WAP
Water flow rate ($L.second^{-1}$)			
0.085	70.85 p	111.75 p	109.96 p
0.336	54.56 p	94.93 p	104.36 p
Surface cover plant density			
10%	49.36 b	92.23 b	94.04 b
20%	51.49 b	93.15 b	98.47 ab
40%	73.07 a	106.75 ab	114.97 ab
60%	76.91 a	121.23 a	121.17 a
Interaction	(-)	(-)	(-)
CV (%)	18.98	15.68	18.48

Remarks: Means followed by the same letters in the same column were not significantly different based on DMRT at α = 5%. The (-) sign shows no interaction between factors; WAP: Week After Planting.

cover showed a significantly higher total plant fresh weight compared to the 10% and 20% surface cover. In the 5 WAP, the 60% surface cover showed a significant higher total plant fresh weight only compared to the 10% surface cover. The 60% surface cover showed significantly higher result on the plant fresh weight compared to other surface cover plant densities as the plant population correlated positively with the plant fresh weight in the five weeks. The higher number of plants existed leads to the higher value of plant fresh weight. Food and Agriculture Organization (2017) states that duckweed plants can divide into two in a span of 16–48 hours.

60% and 40% surface cover resulted in significantly higher plant dry weight compared to the 20% and 10% surface cover at 1 WAP (Table 13). Different result was obtained at 3 and 5 WAP, in which the surface cover plant density showed no significant effect on the total plant dry weight as there was no difference in the growth rate of the duckweed plants, resulting in small amount of assimilates accumulation. The 60% surface cover resulted in higher plant dry weight compared to the 10% surface cover as the 60% surface cover had higher plant population. This result is supported by study of Sitompul and Guritno (1995) and Maisura et al. (2014), who state that the dry weight of plants is influenced by the plant growth rate.

Table 13. Total dry weight (g) of duckweed plants at 1, 3, and 5 WAP

Treatments	1 WAP*	3 WAP*	5 WAP
Water flow rate (L.second^{-1})			
0.085	1.94 p	3.20 p	3.49 p
0.336	1.72 p	3.24 p	3.33 p
Surface cover plant density			
10%	1.40 b	3.05 a	3.06 a
20%	1.50 b	3.55 a	3.22 a
40%	2.09 a	3.49 a	3.62 a
60%	2.32 a	2.80 a	3.73 a
Interaction	(-)	(-)	(-)
CV (%)	9.15	17.13	17.85

Remarks: Means followed by the same letters in the same column were not significantly different based on DMRT at α = 5%. The (-) sign shows no interaction between factors. The (*) sign indicates data were transformed using a formula of √(x+0.5); WAP: Week After Planting.

Table 14. The N Content and C/N ratio in duckweed plants (%) at 5 WAP

Treatments	N	C/N
Water flow rate (L.second^{-1})		
0.085	5.26 p	7.17 p
0.336	4.51 q	7.91 q
Surface cover plant density		
10%	4.54 c	7.75 a
20%	4.75 b	7.71 a
40%	5.41 a	7.04 a
60%	4.85 b	7.66 a
Interaction	(-)	(-)
CV (%)	16.01	7.05

Remarks: Means followed by the same letters in the same column were not significantly different based on DMRT at α = 5%. The (-) sign shows no interaction between factors; WAP: Week After Planting).

Higher water flow rate significantly increased the N content in the duckweed pants (Table 14). The 40% surface cover resulted in the highest N content compared to other surface cover plant densities as the 40% surface cover provided more space to grow than the 60% surface cover so that the plants were less stressed, and they could grow properly. This result is supported by Holshof et al. (2009), who stated that the high population of duckweed plants on the surface of the water could have a negative impact on the water quality and caused odor as the biochemical processes in the plant's body were disrupted due to the changes by the environmental conditions. Thus, the plant population of duckweed plants on a pond is important to maintain so that these plants can grow and reproduce optimally. The 40% surface cover showed the highest N content compared to the 10% and 60% surface cover because the plant growth at a density of 40% reached the optimal rate. Skillicorn et al. (1993) state that since 1970, duckweed plants have been used due to the high content of N or protein. In addition, this plant also contains other important nutrients.

There was no interaction effect of water flow rate and surface cover plant density on the value of C/N ratio (Table 14). Hasan and Chakrabarti (2009) state that the most important nutrition for duckweed plant growth is nitrogen. In this study, the value of C/N ratio of plants obtained was in the range of 6.52–8.30. This value indicates that if the duckweed plants will be used as organic fertilizer, composting is not necessary. This plant can be applied directly both in fresh or dried form as its C/N ratio value exceeds the C/N ratios of the soil so that this plant does not require any additional of organic material to be able to decompose in the soil. According to Setyorini et al. (2004), the ideal C/N ratio is about 10–12 as it approaches C/N of the soil so that plants can absorb nutrients from fertilizers that have been firstly composted. Thus, if duckweed plants will be used as an organic fertilizer, the plants can directly absorb the nutrients contained in the ducked plants as they are easily decomposed.

In the 3 WAP, the 60% surface cover resulted in higher water content compared to the 40% and 10% surface cover, which was not significantly different from the water content resulted by the 20% surface cover (Table 15). This result was due to the higher number of plants in the 60% surface cover, thereby resulting in the higher water content. According to Heuze and Tran (2015), the duckweed plants have a water content around 92-95%. Thus, when the plants are harvested, they are very thick and perishable.

The following suggestions are given for further research as considered from the research that has been done, (1) Research should be in a wider area so that plants can breed optimally; (2) Each side of the test plot to be filled with water must be fenced by a net so that plants do not come out when the water exceeds the test plot; (3) The inlet and outlet of the water flow of the test plot should be maintained; (4) The depth of the test plot should be more than 30 cm

Table 15. Water content in duckweed plants (%) at 1, 3, and 5 WAP

Treatments	1 WAP*	3 WAP*	5 WAP
Water flow rate (L.second^{-1})			
0.085	37.04 p	36.94 p	30.62 p
0.336	32.27 p	31.08 p	30.28 p
Surface cover plant density			
10%	35.63 a	30.84 ab	29.76 a
20%	34.03 a	29.50 b	29.46 a
40%	35.70 a	31.06 ab	30.74 a
60%	33.25 a	44.61 a	31.82 a
Interaction	(-)	(-)	(-)
CV (%)	16.01	15.49	9.35

Remarks: Means followed by the same letters in the same column were not significantly different based on DMRT at α = 5%. The (-) sign shows no interaction between factors. The (*) sign indicates data were transformed using a formula of √(x+0.5); WAP: Week After Planting).

so that the volume of water is accommodated more, and it does not experience silting; (5) The application of duckweed plants as green fertilizer should be stepped on and buried in paddy fields as they have a low C/N ratio so that they can be used directly as green fertilizer.

CONCLUSIONS

The water flow rate did not significantly affect the growth and yield quality of duckweed plants. The highest result of total fresh weight was obtained in the treatment of 60% initial surface cover, but not yet significantly different compared to the result of 20% and 40% initial surface cover. The highest N content was obtained in the treatment of 40% initial surface cover. Meanwhile, The C/N ratio of duckweed plants fulfilled the requirement to be used as green manure.

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