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Research Article
Effect of Size and Thickness of Mulch on Soil Temperature, Soil Humidity, Growth and Yield of Red Beetroot (*Beta vulgaris* L.) In Jatikerto Dry Land, Indonesia

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Abstract

Background and Objective: The impact of land-use change encourages the development of agricultural businesses directed at sub-optimal land use, such as dry land. However, because one of the characteristics of dry land is a high temperature and a low level of water availability, environmental engineering such as the use of mulch needs to be done. Therefore, this study aimed to determine the effect of different parameters on Red Beetroot. **Materials and Methods:** The study used a split-plot design and each treatment combination was repeated three times. Paddy straw mulch length, which is 30 and 10 cm is placed in the main- plot, while the thickness of mulch (without mulch, mulch thickness of 2, 4, 6 and 8 cm) was placed in sub-plots. F test at 5% is used to determine the effect of treatments, while differences between treatments were referred to Honestly Significant Difference (HSD) value at 5%. **Results:** The use of 10 cm mulch length at a mulch thickness of 2, 4, 6 and 8 cm is able to suppress the maximum soil temperature of 4.41, 5.17, 5.07 and 4.9°C, respectively, but followed by an increase in minimum soil moisture of 2.2, 4.5, 6.1 and 17%, compared to the use of 30 cm mulch length. In the same treatment combination, the tuber yield per hectare also increased by 3.09, 15.48, 17.25 and 25.91% compared to the use of 30 cm mulch length. **Conclusion:** In general, the application of mulch at various lengths and thicknesses has a positive effect on all parameters observed, including plant microclimate, plant growth and tuber yields per hectare, rather than without mulching. In the treatment without mulch, all parameters produced were the lowest, while the higher ones were obtained in a combination of a mulch length of 10 cm with a mulch thickness of 8 cm.

Key words: Paddy straw mulch, thickness, mulch length, microclimate of plants, red beetroot

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

A healthy lifestyle has become a decision for every human being. This is what drives most Indonesian people to have a healthy lifestyle by consuming healthy and quality food. Based on this desire, the red beetroot tubers began to be recognized and favored by most Indonesian people. This is quite relevant because the tubers contained a number of nutrients, vitamins and minerals that are complete and beneficial for the health of the human body[1]. Based on the full content of these nutrients, causing red beetroot can be used to prevent cancer, reduce blood pressure and maintain heart health, help facilitate digestion and weight loss. Their betalain contained in the bulb also serves as a natural dye textiles and food products. Due to the high benefits of these bulbs, the demand for red beetroot increased by around 2%. However, these requests have not been able to meet because of the low level of availability.

Red beetroot plants originate from sub-tropical regions, therefore, in Indonesia, the plants grown in the highlands are characterized by low temperatures. The optimum temperature for plant growth and development is 12-19°C with a maximum temperature of about 35°C[2]. However, with the limited area of the highlands (in Indonesia), whether caused by land conversion activities as well as more diverse horticultural developed in Indonesia, to encourage the development of red beetroot crop to a lower region, especially to dry land. This decision was based on several considerations, including Indonesia's land area is 78% dominated by dry land[3], there are still ±12.2 M ha of dry land that has not been used intensively for agriculture activities and along with the development of industrial and residential interests, the development of agricultural businesses today have been directed at land-use problems such as dry land. Meanwhile, the obstacles faced in managing dry land are quite complex, one of which is the low availability of water for plants. The source of irrigation in this region is only dependent on rain water, the wet period only lasts for 3-4 months/year with uneven distribution. These constraints is also supported by the high intensity of the radiation received by the ground surface which resulted in a decrease in the level of soil moisture due to the high rate of evapotranspiration[4]. In fact, to get the highest yield of red beet tubers in dry land requires the highest amount of water, which is 1150 mm/season. Another factor that causes a low level of water availability in dry land is the high infiltration rate due to overly porous soil or due to cracked soil. This is quite relevant because most of the dry land is dominated by inceptisol or alfisol types. This condition is also found in the Jatikerto experimental garden where this experiment will be conducted. Referring to the issues and based on the important role of water for plants, particularly for red beetroot plants, environmental engineering need to be done, namely through mulching[3].

Chen *et al.*[5] stated that soil water loss through evapotranspiration can reach a quarter of the total evapotranspiration. Therefore, the main strategy that should be applied in water management in dry lands is efficiency[6]. Efficient in the sense that the loss of water just for the sake of growth and development of plants that can be actualized through transpiration activity and metabolism. Mulching also serves to regulate temperature and soil moisture. McMillen[7] reported that the application of mulch was able to suppress the maximum high temperature, an average of around 0.54°C and was able to increase the minimum temperature around 0.44°C and this becomes important for the development of red beetroot plants. Nevertheless, the influence of mulch application on the formation of a micro-plant environment will be strongly influenced by the lengths and the thickness of the mulch applied. Therefore the purpose of this study was to determine the size and the thickness of straw mulch suitable for the growth and yield of beetroot crops in the dry land.

MATERIALS AND METHODS

Study area: A field experiment has been carried out in the Brawijaya University experimental garden in Jatikerto Village, Kromengan District, Malang Regency, Indonesia from March-May, 2019. The location is at an altitude of 330 m above sea level, in the form of dry land with Alfisol type. Climatologically, the average annual rainfall of 1200 mm with an average daily temperature of around 24-31°C[8].

Research material: Planting material in the form of red beetroot seeds of Crimpson globe 3 variety which has been aged 21 days after seedling, paddy straw as mulch material, consist of two length, namely 10 and 30 cm N fertilizer in the form of urea (46% N), phosphate fertilizer in the form of SP_{36} (36% P_2O_5), Potassium fertilizer in the form of KCl (60% K_2O) respectively of 458 kg urea ha^{-1}, 505 kg SP_{36} ha^{-1} and as much as 140 kg KCl ha^{-1}. Phosphate fertilizer was applied at the beginning of planting all doses, while for urea and KCl fertilizers were given in stages each half of the dose. Stage 1 was applied when the plants were 7 days after planting and the rest when plants were 14 days after planting. Fertilizer was applied on the left or right side of the plant with a distance of 5 cm and with a depth of 7 cm.

Experimental design: The experiment used a Split-plot Design (SPD) and was repeated 3 times. The length of paddy straw mulch as the main plot consists of two sizes, namely 10 and 30 cm and the thickness of the paddy straw mulch, which is 2, 4, 6 and 8 cm as subplots. F test at 5% level is used to determine the interaction or the significant effect of the treatment. As for knowing the difference between treatments refers to Honestly Significant Difference (HSD) test at 5%. Regression analysis is used to explore the relationship between two or more variables observed[9].

Research implementation: Paddy straw mulch is applied before planting by spreading it over the surface of the soil to the size and thickness according to treatment. The thickness of the mulch is maintained until harvest by controlling its thickness regularly. The calculation of paddy straw mulch needs based on its thickness According to Pradana *et al.*[10] are as follows:

Paddy straw mulch:

$$\text{Mulch requirements per plot} = \text{Mulch requirements} \times \text{Plot size} \times \text{Thickness of mulch}$$

where, plot size: 5.04 m^2.

Dosage recommendation: About 5 ton ha^{-1} to a thickness of 3 cm = 0.17 kg m^{-2} to a thickness of 1 cm. Thickness of 2 cm = 0.17 kg $m^{-2} \times 5.04\ m^2 \times 2$ cm = 1.71 kg.

Based on the above calculation, the need for paddy straw mulch for thicknesses of 2, 4, 6 and 8 cm are presented in Table 1.

Planting is done by placing 1 bit of plant seeds/planting hole when the plant has 21 days after seeding or have formed two leaves have fully opened. As planting material, seeds are selected that are uniform and healthy. Plant spacing used is 40×20 cm.

Observation: Data collection for observations of the microenvironment is done periodically when plants are 13 days after planting (daps), 23, 33 and 43 daps include measurements of minimum and maximum soil temperatures, as well as minimum soil moisture. As for the plant growth observations were carried out destructively by taking 3 sample plants for each treatment combination. Measurements were taken when the plants were 15 days after planting (daps), 25, 35 and 45 daps, which included measurements of root dry weight, leaf surface area and total dry weight of the plant. The harvest observations were carried out destructively by taking as many as 15 sample plants/plots (1.2 m^2).

Table 1: Paddy straw mulch needs to a thickness of 2, 4, 6 and 8 cm for size 10 and 30 cm with a plot size of 5.04 m^2

Number	Thickness level of paddy straw mulch (cm)	Paddy straw mulch needs per plot (kg)
1	2	1.71
2	4	3.43
3	6	5.14
4	8	6.85

Data collection

Plant microenvironment

Soil temperature: Soil temperature is measured using an alcohol thermometer, placed about 7 cm from the plant, both for maximum and minimum temperature. The minimum temperature is observed every 05.00 am and for the maximum temperature observed at 13.30 pm.

Soil moisture tester: Minimum soil moisture was observed by using AMTAST KS05 Soil Moisture tester. Observations made by pressing the button on the device before it is plugged into the ground. Soil moisture tester is driven into the ground as deep as 10 cm and is left up to the number shown on the instrument is not changed and then recorded. Minimum soil moisture was observed at 13:30 pm.

Plant growth parameters

Root dry weight: Root dry weight measurement is done by separating the roots from the tuber or stem. Roots that have been separated, then put into a cement paper bag that has been given a treatment code, then put in an OVL 12 oven with a temperature of 81°C until a constant weight is achieved, then weighed with a Scout-pro type analytical balance[11].

Leaf surface area: Leaf surface area is determined for leaves that have fully opened, not including young leaves or old leaves that have undergone senescence, using a leaf area meter type LI-3100 C. Leaves are separated from the leaf stalks, then placed on a glass lens in a position not folded. Leaves that are too wide are cut into 2 or 3 parts. The recording was made based on the numbers on the device until the end of the leaf samples for each treatment. Leaf surface area is determined by multiplying the leaf surface area by a correction factor. A correction factor is determined by dividing the paper area after measured by a tool (eg. 90 cm^2) with an area of actual paper (eg 100 cm^2), so the value of the correction factor is 0.90[11].

Total dry weight of plants: Measurement of the total dry weight of the plant is done by using an oven-type OVL 12 with a temperature of 81°C. Samples of plants that will be put in the oven should be separated between the plant parts, such as roots, stems, leaves and tubers. This is because to achieve a constant dry weight takes different times. Before entering into a paper bag of cement and into the oven, sample plants should be chopped in order to obtain uniform drying and after reaching a constant dry weight, the sample removed from the oven, then weighed using an analytical balance Scout-pro type and summed[11].

Harvest

Tuber weight per hectare: Calculation of tuber weights per hectare is obtained from the conversion of yields per harvest plot (5.04 m^2) to units of hectares using the Eq.[8]:

$$\text{Yield per hectare} = \frac{\text{Land area of 1 ha} \times \text{Tuber weight}}{\text{Harvest plot}} \times 0.90$$

where, harvest plot area (5.04 m^2).

RESULTS

Plant microenvironment

Minimum soil temperature: There was no significant interaction between mulch length and mulch thickness at minimum soil temperatures. However, the minimum soil temperature is affected by the lengths and thickness of the mulch, as presented in Table 2.

Table 2 shows that higher minimum soil temperature is generally obtained at a mulch length of 10 cm compared to a size of 30 cm. Whereas for the treatment of mulch thickness it was found that the use of mulch thickness of 2-6 cm, generally the minimum soil temperature showed no significant difference at p = 0.05 with treatment without mulch and at mulch thickness of 8 cm. However, through the application of 8 cm thickness mulch is able to produce minimum soil temperature higher than without mulching. Whereas at the age of 33 daps, the use of mulch thickness of 2 and 4 cm, the minimum soil temperature produced was not significantly different at p = 0.05 with treatment without mulching and with mulch thickness of 6 and 8 cm. However, for mulch applications a thickness of 6 and 8 cm can produce a minimum soil temperature higher than without mulching.

Maximum soil temperature: There was a significant interaction between mulch length and mulch thickness at a maximum soil temperature of 33 daps, as presented in Table 3.

Table 3 shows that at a mulch length of 30 cm, the maximum soil temperature showed no significant difference at p = 0.05 for mulch thickness of 2, 4 and 6 cm with treatment without mulching and with mulch thickness of 8 cm. However, for treatment without mulch, the maximum soil temperature produced is higher than mulch thickness of 8 cm whereas, for the use of 10 cm mulch length, the highest maximum soil temperature was obtained in the treatment without mulching. Application of 4 and 6 cm mulch thickness, resulting in maximum soil temperature that is not significantly different at p = 0.05 from the application of mulch thickness of 2 and 8 cm. However, the application of 2 cm mulch thickness

Table 2: Average minimum soil temperature at two mulch lengths and various mulch thicknesses at four observational ages

	Average minimum soil temperature (°C) at four observational ages (dap)			
Treatment	13	23	33	43
Mulch lengths (cm)				
30	22.45	23.39^{a}	22.65	23.34^{a}
10	22.91	26.65^{b}	23.07	26.63^{b}
HSD 5%	ns	3.19	ns	3.21
Mulch thickness level (cm)				
Without mulch	21.30^{a}	22.97^{a}	21.49^{a}	22.98^{a}
2	22.10^{ab}	24.89^{ab}	22.33^{ab}	24.49^{ab}
4	22.81^{ab}	25.32^{ab}	22.99^{ab}	25.47^{ab}
6	23.35^{ab}	25.77^{ab}	23.52^{b}	25.89^{ab}
8	23.84^{b}	26.16^{b}	24.0^{b}	26.11^{b}
HSD 5%	2.19	2.98	1.99	3.07

Numbers that are accompanied by the same letter in the same treatment and column are not significantly different at HSD 5%, dap: Days after planting, ns: Not significant effect

Table 3: Average maximum soil temperature at two different levels of long-mulch and mulch thickness at the age of 33 daps

	Mulch thickness level (cm)				
Treatment	Without mulch	2	4	6	8
Mulch length (cm)					
30 cm	33.20^{b}	32.88^{ab}	32.30^{ab}	31.54^{ab}	31.13^{a}
	A	B	B	B	B
10 cm	33.29^{c}	28.47^{b}	27.13^{ab}	26.47^{ab}	26.23^{a}
	A	A	A	A	A
HSD 5%	2.01				

Numbers that are accompanied by the same letters in the same row, or the same capital letters in the same column are not significantly different based on the HSD test at a 5% level, daps: Days after planting

Table 4: Average minimum soil moisture at two different levels of long-mulch and mulch thickness at the age of 33 daps

	Mulch thickness level (cm)				
Treatment	Without mulch	2	4	6	8
Mulch lengths (cm)					
30 cm	30.17^{a}	33.57^{ab}	35.00^{ab}	38.67^{b}	40.83^{b}
	A	A	A	A	A
10 cm	30.40^{a}	35.77^{ab}	39.50^{b}	44.77^{b}	57.83^{c}
	A	A	A	B	B
HSD 5%	5.70				

Numbers that are accompanied by the same letters in the same row or the same capital letters in the same column are not significantly different based on the HSD test at a 5% level, daps: Days after planting

capable to produce a maximum soil temperature higher than a mulch thickness of 8 cm. When viewed from the effect of mulch thickness on two mulch lengths, it was found that with the use of 30 cm long the mulch was able to produce a maximum soil temperature higher than the 10 cm mulch length, except for treatment without mulch.

Minimum soil moisture: There was a significant interaction between mulch length and mulch thickness at minimum soil moisture of 33 daps as presented in Table 4.

Table 4 shows that at a mulch length of 30 cm, the minimum soil moisture produced by mulch thickness of 2 and 4 cm was not significantly different at p = 0.05 with treatment without mulch and with mulch thickness of 6 and 8 cm. However, mulch thickness of 6 and 8 cm showed higher results than without mulch, although the two treatments were also not significantly different at p = 0.05. As for the length of 10 cm mulch, the highest minimum soil moisture was found in mulch thickness of 8 cm. Reducing the thickness of the mulch from 8 cm to being without mulch, reduces the minimum soil moisture value produced. The use of mulch thickness of 2 cm produces minimum soil moisture which is not significantly different from mulch thickness of 4 and 6 cm. However, with the application of mulch thickness of 4 and 6 cm, the resulting minimum soil moisture was higher than treatment without mulch. Effect of mulch thickness on minimum soil moisture on two mulch lengths shows that the use of mulch lengths of 30 and 10 cm, the minimum soil moisture produced was not significantly different at p = 0.05 in treatments without mulch, or with mulch thickness of 2 and 4 cm. However, with the application of 6 and 8 cm thickness of mulch, higher minimum soil moisture was obtained at a mulch length of 10 cm.

Plant growth parameter

Root dry weight: There was a significant interaction between mulch length and mulch thickness on root dry weight at 35 daps as presented in Table 5.

At a mulch length of 30 cm, the highest root dry weight was obtained in mulching applications with a thickness of 8 cm. In treatments without mulch, or with 2 cm thickness mulch, the dry root weight produced was lower compared to the mulching thickness of 4 cm. Although for both treatments (without mulch and mulch thickness of 2 cm, did not show different results at p = 0.05. In this study, it was demonstrated that the application of mulch thickness of 4 cm, root dry weight produced was lower than mulch thickness of 6 cm. On the other hand, at the use of 10 cm long mulch, the highest root dry weight was obtained in mulch application thickness of 8 cm and the lowest was obtained in the treatment without mulching. Increasing the thickness of the mulch every level is always followed by an increase in root dry weight proportionally. The results showed that with the use of mulch thickness of 2 cm, the resulting root dry weight lower than the mulch thickness of 4 cm and mulching thickness of 4 cm, root dry weight also showed lower than mulch thickness of 6 cm.

Fig. 1(a-j): Development of red beetroot roots at 35 daps

(a) Treatment without mulching as a control for the use of mulch length of 30 cm (B_1K_0), (b) combination of 30 cm mulch length with mulch thickness of 2 cm (B_1K_1), (c) combination of 30 cm mulch length with mulch thickness of 4 cm (B_1K_2), (d) combination of 30 cm mulch length with 6 cm thickness mulch, (e) combination of 30 cm mulch length with 8 cm thickness mulch (B_1K_4), (f) Non-mulch treatment as a control for the use of 10 cm mulch length (B_2K_0), (g) combination of a 10 cm mulch length with 2 cm thickness mulch (B_2K_1), (h) combination of a 10 cm mulch length with 4 cm thickness mulch (B_2K_2), (i) combination of a 10 cm mulch length with 6 cm thickness mulch (B_2K_3) and (j) combination of 10 cm mulch length with mulch thickness of 8 cm (B_2K_4), B_1: 30 cm mulch length, B_2: 10 cm mulch length, K_1: 2 cm mulch thickness, K_2: 4 cm mulch thickness, K_3: 6cm mulch thickness, K_4: 8 cm mulch thickness and K_0: Treatment without mulching

Table 5: Average root dry weight (g) at two mulch lengths and various mulch thickness at 35 daps

	Mulch thickness level (cm)				
Treatment	Without mulch	2	4	6	8
Mulch lengths (cm)					
30 cm	0.092^{a}	0.103^{a}	0.147^{b}	0.184^{c}	0.226^{d}
	A	A	A	A	A
10 cm	0.089^{a}	0.117^{b}	0.170^{c}	0.210^{d}	0.274^{e}
	A	B	B	B	B
HSD 5%	0.016				

Numbers that are accompanied by the same letters in the same row, or the same capital letters in the same column are not significantly different based on the HSD test at a 5% level, daps: Days after planting

Effect of different levels of mulch thickness to length mulch demonstrated that at a thickness of 2-8 cm, higher root dry weight generally obtained in the mulch length of 10 cm, except on treatment without mulch. But overall the roots formed are still below normal. Development a root of beetroot at 35 daps as presented in Fig. 1.

Leaf surface area: There was a significant interaction between mulch length and mulch thickness on leaf surface area at 35 daps as presented in Table 6.

Table 6 shows that the use of mulch 30 cm long, a wider leaf area surface was obtained in the treatment of 6 and 8 cm mulch thickness and both showed were not significantly different. Reducing the level of mulch thickness, from 8 cm to no mulch, causes the leaf surface area to decrease proportionally. The narrowest leaf area was obtained in the treatment without mulch

However, with the use of 10 cm long mulch, the widest leaves were found in the 8 cm mulch application and showed a decrease with the decreases in the thickness of the mulch, from 8 cm to no mulch. Leaf surface area showed no significant difference in mulch thickness of 4 and 6 cm. However, the leaf area produced by the two treatments was still wider than the use of mulch with a thickness of 2 cm, or

Table 6: Average leaf surface area (cm^2) at two mulch lengths and various mulch thicknesses at 35 daps

	Mulch thickness level (cm)				
Treatment	Without mulch	2	4	6	8
Mulch lengths (cm)					
30 cm	241.40^{a}	329.42^{b}	380.17^{c}	487.15^{d}	526.67^{d}
	A	A	A	A	A
10 cm	245.43^{a}	457.55^{b}	513.25^{c}	544.70^{c}	592.85^{d}
	A	B	B	B	B
HSD 5%	47				

Numbers that are accompanied by the same letters in the same row, or the same capital letters in the same column are not significantly different based on the HSD test at a 5% level, daps: Days after planting

Table 7: Average total dry weight of plant (g) at two mulch lengths and various mulch thicknesses at 35 daps

	Mulch thickness level (cm)				
Treatment	Without mulch	2	4	6	8
Mulch length (cm)					
30 cm	3.25^{a}	3.63^{a}	4.68^{b}	5.39^{c}	6.04^{d}
	A	A	A	A	A
10 cm	3.30^{a}	5.25^{b}	5.75^{c}	6.21^{d}	7.22^{e}
	A	B	B	B	B
HSD 5%	0.45				

Numbers that are accompanied by the same letters in the same row, or the same capital letters in the same column are not significantly different based on the HSD test at a 5% level, dap: Days after planting

Table 8: Average tuber weight per hectare (ton) at two mulch lengths and various mulch thickness at harvest

	Mulch thickness level (cm)				
Treatment	Without mulch	2	4	6	8
Mulch length (cm)					
30 cm	5.86^{a}	6.14^{a}	6.46^{a}	7.19^{b}	7.41^{b}
	A	A	A	A	A
10 cm	5.97^{a}	6.33^{a}	7.46^{b}	8.43^{c}	9.33^{d}
	A	A	B	B	B
HSD 5%	0.69				

Numbers that are accompanied by the same letters in the same row, or the same capital letters in the same column are not significantly different based on the HSD test at a 5% level

without mulch. Judging from the effect of mulch thickness on two sizes, it was found that wider leaf surfaces were generally obtained at sizes 10 cm rather than 30 cm, except for treatment without mulching.

Total dry weight of plant: There was a significant interaction between mulch length and mulch thickness on total dry weight of plant at 35 daps, as presented in Table 7.

Table 7 shows that the use of a 30 cm mulch length, the highest total dry weight of plant was obtained in the 8 cm thickness mulch application. Meanwhile, the lower one was obtained in the treatment without mulch and with mulch thickness of 2 cm and both showed no significant difference at $p = 0.05$. The total dry weight of plant showed an increase when followed by an increase in the thickness of the mulch and the increase occurs proportionally with increasing thickness of the mulch. As for the length of mulch 10 cm, the highest total dry weights of plant were also obtained on the thickness of the mulch 8 cm. The total dry weight of the plant showed a decrease when the mulch thickness level was lowered, both for each thickness level, as well as for various thickness levels up to the no-mulch treatment. The lowest total dry weight of plant was obtained in the treatment without mulch.

Harvest

Tuber weight per hectare: There was a significant interaction between the length and thickness of the mulch on the weight of tuber per hectare at harvest as shown in Table 8.

On the use of mulch 30 cm long, the higher tuber yield per hectare was obtained on application mulch thickness of 6 and 8 cm than other treatments and both showed no significantly different results. The yield of tubers per hectare showed no significantly different results in the treatment

Fig. 2(a-j): Observation of tubers harvested at various length and thickness of the mulch
(a) Treatment without mulching as a control for the use of mulch length of 30 cm (B_1K_0), (b) combination of 30 cm mulch length with mulch thickness of 2 cm (B_1K_1), (c) combination of 30 cm mulch length with mulch thickness of 4 cm (B_1K_2), (d) combination of 30 cm mulch length with 6 cm thickness mulch, (e) combination of 30 cm mulch length with 8 cm thickness mulch (B_1K_4), (f) Non-mulch treatment as a control for the use of 10 cm mulch length (B_2K_0), (g) combination of a 10 cm mulch length with 2 cm thickness mulch (B_2K_1), (h) combination of a 10 cm mulch length with 4 cm thickness mulch (B_2K_2), (i) combination of a 10 cm mulch length with 6 cm thickness mulch (B_2K_3) and (j) combination of 10 cm mulch length with mulch thickness of 8 cm (B_2K_4), B_1: 30 cm mulch length, B_2: 10 cm mulch length, K_1: 2 cm mulch thickness, K_2: 4 cm mulch thickness, K_3: 6 cm mulch thickness, K_4: 8 cm mulch thickness and K_0: Treatment without mulching

without mulch, with mulch the thickness of 2 and 4 cm. Whereas in the use of 10 cm long mulch, the highest tuber yield was obtained in 8 cm mulch application and showed a decrease with the reduction in the thickness of the mulch from 8 cm to no mulch. The reduction in the thickness of the mulch, from 4 cm or 6 cm to no mulch, also resulted in lower tubers per hectare produced. Lower tuber yields were obtained in the treatment without mulch and with mulch with a thickness of 2 cm. The observation of tubers harvested at various lengths and thickness of the mulch is presented in Fig. 2.

DISCUSSION

The results showed that at various ages of observation, the use of a mulch size of 10 cm was able to produce a higher minimum soil temperature than using a mulch size of 30 cm. This is because, with the use of 10 cm mulch, the ability of mulch to cover the soil surface is more evenly compared to mulch along 30 cm[12]. As a result, the radiation energy received by the ground surface lower than the surface of which is covered with a length of 30 cm mulch. Even though the energy received by the soil surface is low, but the ability of mulch to cover the soil surface is very high, causing a high barrier to release the energy that has been absorbed into the atmosphere[13,14]. As a result, the minimum soil temperature that is formed is still higher than the 30 cm mulch-covered soil surface, because energy is still stored in the soil. Meanwhile, for the thickness mulch treatment, it was found that the use of mulch with a thickness of 8 cm, the minimum soil temperature produced was higher than without mulch. This is because in the without mulch treatment, the soil surface is in direct contact with the sun so that the radiation energy received by the soil surface during the day is quite high compared to the soil covered with mulch, especially with a thickness of 8 cm. However, because this soil has the properties as "Black Body Radiation", the energy that has been absorbed, within a certain time (until the sun sets), the energy will be released back into the atmosphere[15]. As a result, the energy stored in the soil decreases and this lasts until the minimum soil temperature is reached.

Maximum soil temperature is observed during the day and its fluctuations are greatly influenced by the level of thickness and perfection of the mulch in covering the soil surface. The results showed that the highest maximum soil temperature was obtained in the treatment without mulch, for both lengths of mulch (30 and 10 cm), while the lowest was obtained in 8 cm mulch application. The higher the maximum soil temperature is due to the absence of obstacles that must be passed by the sun when it reaches a surface. Mulch will act as a barrier in receiving radiation energy which causes a reduction in radiation energy received by a surface[2]. The results of this study also indicated that in various treatments of mulch thickness (2, 4, 6 and 8 cm), higher maximum soil temperature was generally obtained on the use of 30 cm mulch length rather than 10 cm. This is closely related to the more solar radiation energy that can be received by the soil surface that is given a 30 cm mulch as a result of the formation of gaps that allow energy to reach a surface. These results are in line with the results of the study of Pradana *et al.*[10] who found that with the application of 6, 4 and 2 cm thickness of mulch straw, the maximum soil temperature produced was 15.57% (around 4.67°C), 7.77% (about 2.33°C) and 5,57% (around 1.67°C) is lower than without mulch which has reached 30°C. On the other hand, the presence of a back emission of energy that has been absorbed by the surface causes additional energy which causes higher air temperature which will then have an impact on increasing soil temperature[11]. Based on regression analysis found a linear relationship between the thickness of the mulch (X) with maximum soil temperature (Y) for the length of 30 cm mulch as given by the following Eq:

$$Y_{30cm} = -0.27X + 33.31,\ R^2 = 0.98$$

However, for the use of 10 cm mulch length, a quadratic equation is obtained as follows:

$$Y_{10cm} = 0.18X^2 - 2.21X + 32.95,\ R^2 = 0.97$$

Through this equation, it can be determined that the optimum thickness of the mulch is 6.14 cm, with the highest maximum soil temperature of 26.17°C. Research results by Dewantari *et al.*[13] found that by using straw mulch without chopping, the maximum soil temperature produced was 0.61% (0.16°C) higher than the chopped straw mulch which reached a value of 26.17°C.

Soil moisture reflects the amount of water vapor contained in the soil[7] and from this study, it was found that the lower minimum soil moisture for both mulch lengths (30 and 10 cm) was obtained in the no-mulch treatment which was 30.17%. While the higher was obtained at 6 and 8 cm thickness of mulch, respectively 38.67 and 40.83%. The low minimum soil moisture is closely related to the higher temperature formed due to the high radiation energy received by the treatment without mulch. In high-temperature conditions, a certain amount of water will be released through the ground surface into the atmosphere as a result of increasing the evaporation rate. As a result, the remaining water in the soil is reduced which in turn results in lower minimum soil moisture produced. This incident is in line with the opinion of Wijewardana *et al.*[15] which states that mulch is able to prevent groundwater evaporation, thereby helping to retain soil moisture.

Its higher soil temperatures and lower soil moisture generated by the treatment without mulch caused a lower root dry weight produced. This is quite relevant because the development of plant roots is very much determined by the availability of assimilate which acts as growth energy. In low water conditions, plants will experience various physiological problems, including inhibition of the chlorophyll biosynthesis process caused by disruption of the nitrification process which causes low N availability for plants[16]. While N was instrumental in the formation of chlorophyll, both chlorophyll-a ($C_{55}H_{72}O_5N_4Mg$) and chlorophyll b ($C_{55}H_{70}O_6N_4Mg$), which plays a role in the absorption of radiation energy that causes the activity of photosynthesis takes place[12]. Therefore, when the water under limited conditions the process of plant growth is hampered by the disruption of the process of cell division and enlargement, including the development of plant roots. The results of research by Suminarti *et al.*[9] also found that beet plants watered as much as 350 mm/season, root length shorter produced 3.67 cm (68.88%) compared to the watered as much as 750 mm/season up to 9 cm.

Statistically, the widest leaf surface area was found in mulch thickness of 8 cm and the narrowest was obtained in the treatment without mulch, both for mulch lengths of 30 and 10 cm. The narrowest leaf area is related to the lower minimum soil moisture and the lower root dry weight produced. In such conditions, plant growth and development will be disrupted due to less than an optimal growing environment for plants, especially water. Roots that act as absorbers of nutrients and water for plants cannot function normally because of the low energy produced for the root formation process. This is because plants are not able to carry out normal photosynthetic activities[6]. As a result, the resulting assimilate is low which causes disruption of the plant growth rate, including the leaf expansion process.

The lower root dry weight produced illustrates the abnormal root development process, so it will affect the ability of the roots to absorb water and nutrients that are needed by plants. The availability of sufficient water and nutrients is needed by plants to encourage their growth process. If a plant is deficient in one or many types of nutrients, plant production is largely determined by the lowest conditions of these nutrients. One way for plants to respond to water shortages is by reducing the rate of transpiration. In extreme weather conditions, the high loss of water from the soil is proportional to the rate of evapotranspiration and if in this condition there is not enough water available in the soil, the plants will wither[6]. This is because the rate of water loss is faster than the rate of water absorption by plant roots. This wilting is a way of adapting plants to deal with drought stress, although in fact, this method is very detrimental for plants[17].The research result Dewantari *et al.*[13] found that leaf area in treatment without mulch was 802,28 cm^2 and the value was still lowered 48.26% (387.16 cm^2) compared to straw mulch treatment which reached 1189.44 cm^2

The total dry weight of the plant describes assimilate produced by plants and is a function of the plant parts such as roots, stems, leaves and economical parts of plants. When the plant grows normally, it will be followed by the normal growth of the plant parts. The results showed that the highest total dry weight of the plants for the two treatments of mulch length (i.e. 30 and 10 cm) was obtained in mulch application thickness of 8 cm and the lowest was obtained in the treatment without mulch. Some of the factors that cause the low total dry weight of the plant are: the high value of maximum soil temperature, the low value of minimum soil moisture, the low value of the root dry weight of the plant and the narrowest leaf surface area produced. The high maximum soil temperature (ranging from 31-33°C) has the opportunity to spur faster evaporation activities, which in turn has an impact on greater water loss from the ground. As a result, the level of groundwater availability is low. On the other hand, at high temperatures, especially in the leaves, spurring the midday stomatal closure (closure midday)[2]. This stomata closure event will have an impact on reducing the resulting assimilate due to the disruption of photosynthetic activities. On the other hand, the narrow size of the leaf surface area also affects the capacity of plants to carry out photosynthesis. This is what causes the low total dry weight of the plant.

The economic yield of beetroot plants lies in their tubers and the yield of these tubers is largely determined by the amount of assimilate formed. Assimilate that is formed is not entirely allocated to the tubers but some are used for growth energy and some are stored as food reserves[17,18]. Therefore, to find out how many assimilates are distributed to the tubers, it can be approached through the calculation of R/S. (R namely tubers), shoot (S is total fresh weight of the plant). The greater the R/S value, the more assimilates are distributed to the tubers which result in higher tuber yields. Based on calculations it was found that a low R/S value was obtained in the treatment without mulch, which is 0.34, then followed by 2 cm mulch treatment, which is 0.48. That means that of the total assimilates produced only about 34-48% is distributed to the tuber. This is what causes the low tuber weight produced, especially in the treatment without mulch. Although overall that the resulting tuber weight was below normal because it assimilates and the distribution of assimilates to the tuber remains low.

CONCLUSION

Mulch application is able to maintain maximum soil temperature fluctuations and minimum soil moisture better than without mulch. Through mulch application, provide better growth and higher yields on beetroot plants than without mulch. However, the use of 10 cm mulch length with a mulch thickness of 8 cm is more effective and better than a mulch length of 30 cm for all observed variables, including plant microenvironment, plant growth parameters and yields. In the use of mulch length of 30 cm, to achieve better plant growth with high yields, the application of mulch thickness of 8 cm is still inadequate, so mulching thickness of more than 8 cm is needed. The optimal maximum soil temperature for a mulch length of 10 cm (i.e. 26.17°C) is achieved at a mulch thickness of 6.14 cm.

SIGNIFICANCE STATEMENT

This study discovers the effect of length and thickness of paddy straw mulch on plant microclimate, growth and yield of red beetroot in a dry land, so that it can be used as a guideline in the management of red beetroot plants in a dry land. This study will help researchers to uncover the need for mulch, both in terms of the length and thickness of the mulch in red beetroot plants in the dry land. Thus, the discovery of the need for mulch, both long and thick will be able to assist and facilitate the management of red beet plants in dry land in an effort to increase the quantity and quality of red beet tubers in a dry land.

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