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Effect of para-net shade level on plant microenvironment, growth, and yield of three strawberry varieties

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Abstract. *Suminarti NE, Sebayang HT, Maghfoer MD, Bulan. 2023. Effect of para-net shade level on plant microenvironment, growth, and yield of three strawberry varieties. Biodiversitas 24: 2149-2155.* Plant environmental management through the application of para-net shade and the selection of adaptive varieties for strawberry plants has been carried out from March to June 2020 in Jatikerto. The study used a split-plot design by placing shade treatments on the main plot consisting of four types, namely without shade (0%), 25% shading, 50% shading, and 75% shading, while the variety treatment was placed in subplots consisting of three kinds, namely Sweet Charlie, California, and Earlibrite varieties. The 5% F test was used to determine the interaction or significant effect of the treatments, while the 5% HSD test was used to determine differences between treatments. The results showed that there was a significant interaction in observing fruit weight per hectare. In the treatment without shade and with 25% shade, the highest fruit weight was produced by the California variety, 1.06 t ha^{-1}, and 0.80 t ha^{-1}, respectively. Whereas at 50% shade, the highest fruit weight per hectare was found in the Sweet Charlie variety, namely 0.66 t ha^{-1}, and at 75% shade, higher yields were found in the Sweet Charlie and Earlibrite varieties, each of 0.65 t ha^{-1} and 0.55 t ha^{1}. Conclusion: California is a fairly tolerant variety to be developed in the Jatikerto area.

Keywords: Jatikerto, micro-environment, para-net shade, strawberries, varieties

Abbreviations: am: ante meridiem; daps: days after planting; HSD: Honestly Significant Difference

INTRODUCTION

Strawberries are widely known by most levels of Indonesian society. This is because the fruit has a character with unique fruit shape and attractive color. In addition, this fruit also contains several vitamins (A, B, C), minerals (Fe, Ca, K, phosphorus), and nutrients (fats, proteins, carbohydrates) that the human body needs. In line with the increasing public awareness of quality nutrition, the demand for strawberries continues to increase. Ni'matillah et al. (2014) informed that strawberry production in Indonesia in 2021 increased by 18.08% compared to the previous year which only reached 8,350 tons. However, to meet people's needs, Indonesia still imports mainly from America and China.

In Indonesia, strawberry plants are generally grown in highland areas which are characterized by low temperatures and mild climate (Arif et al. 2019). This is following the level of temperature requirements of the strawberry plant, which is around 17-20°C. However, the climate change event has caused an increase in average air temperature of around 0.5-1.5°C in various regions. Even though the increase in temperature is relatively small, it has a large influence on the rate of plant metabolism, such as photosynthesis, respiration, transpiration, and other metabolic systems (Chen et al. 2022). Therefore, to anticipate the increase in air temperature, the management of the plant environment in the form of para-net shade is needed (Mulyani and Sarwani 2013). Temperatures are elements of the climate that have a direct influence on the intensity of photosynthesis reactions, respiration, and other metabolic systems (Chen et al. 2022). At extremely low temperatures (below its optimum limit), it causes the stomata to close due to slow water transportation between the guard cell and the epidermal cell, thereby reducing the pressure of the guard cell turgor (Liu et al. 2014). Conversely, if plants are grown at extremely high temperatures (above the optimum limit), it causes a photoinhibition event, which is the destruction of the photosynthetic system due to excessive light energy captured and cannot be fully utilized in photosynthesis (Hastilestari and Pantouw 2015). While the leaves in this situation do not have the capacity to remove the excess energy through the xanthophyll cycle (Su and Liu 2005). On the other hand, too high a temperature will also have an impact on the destruction of the enzyme, because the enzyme is made of protein (Suminarti et al. 2020). Enzymes will act as a catalyst that determines the intensity or speed of biochemical processes in the plant body. Therefore, if the enzyme were damaged due to high temperature, causing the process of photosynthesis and respiration will be disturbed and even lead to a decrease in yield (Araki et al. 2014).

In addition, the success of developing strawberry plants in Jatikerto areas is also strongly influenced by the varieties planted. This is reasonable because each variety has a different level of adaptation, light saturation, and temperature (Sundari 2009). For varieties that are resistant to new environmental changes, they will be able to grow and develop normally when compared to sensitive varieties (Islam et al. 2020). But a sensitive variety will immediately respond to physiological disorders such as plants becoming weak (Liu et al. 2014). Therefore, through this research, it will be possible to determine the appropriate level of shade and varieties to be planted and developed in the Jatikerto region.

MATERIALS AND METHODS

Study area

A field experiment was carried out in the Brawijaya University experimental garden in Jatikerto Village, Kromengan District, Malang Regency, Indonesia from March-June, 2020. 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. Chemically, the N-soil status is low (0.20%), C-organic is low (1.81%), K-dd (changeable) is medium (0.37 (C mol kg^{-1}), and P-soil status is low (20 ppm). The soil belongs to the sandy loam texture with a proportion of 28% sand: 60% dust: and 12% clay (Suminarti et al. 2020).

Research material

Planting material in the form of seeds from stolons cuttings that are two months old and about 10 cm long, healthy, and not infected by pests or diseases. Planting material obtained from PT. Agro Sentosa Batu consisted of three varieties, namely the California variety, the Sweet Charlie variety, and the Earlbrite variety. While the fertilizers used are N fertilizer (in the form of urea: 46% N), phosphorus (in the form of SP_{36}: 36% P_2O_5), and potassium (in the form of KCl: 60% K_2O). and rice straw. The calculation of fertilizer requirements refers to Suminarti et al. (2021) as shown in equation 1.

$$N = \frac{A2 - B}{A1 - A2} = \frac{N - XA}{XA - XB}$$

Where:

N: the nutrient dose that must be added according to soil criteria (kg h^{-1})

A_1: the top content of the total soil N range (%);

A_2: the lowest content of the total soil N range (%);

B: the total N content of the soil (%); X_A: the highest value of the required dose of N plants (kg h^{-1}): 300 kg N h^{-1}

X_B: the lowest value of the required dose of N plants (kg h^{-1}): 200 kg N $h\text{-}^1$

Based on equation 1 above and the experimental plot area is 5.04 m^2, the fertilization dose that must be given is as presented in Table 1.

Procedures

The initial stage in this research is soil analysis which includes the N, P, and K status of the soil which serves to determine the content of these three elements in the soil. The results of this soil analysis are then used to determine the level of plant N, P, and K fertilizer requirements. The method for calculating the fertilizer requirement follows equation 1. Tillage is done twice. The first tillage is done by plowing to turn over the soil, and the second tillage is done by using a hoe to loosen the soil. Plotting was carried out after the tillage was completed by dividing the land into 3 replications. Each replication was 33.2 m long and 2.6 m wide, consisting of 12 treatment plots. each treatment plot is 5.04 m^2 in size. The next step is the installation of the para-net shade. The para-net shade is rectangular with a height of 1.75 m, a width of 2.6 m, and a length of 7.3 m. The para-net is placed on a bamboo frame with one side that can be opened to make maintenance and observation easier. The para-nets were installed according to the treatment, namely 25% shade, 50% shade, and 75% shade. Planting is done by placing one strawberry seed in the form of stolon cuttings into the planting hole with a depth of 10 cm, then covered with fine soil. P fertilizer was applied 3 days before planting where the doses were 11.42 g SP_{36} per plant. Meanwhile, N fertilizer, as much as 7.84 g urea per plant, and K fertilizer as much as 4.27 g KCl per plant were applied gradually. The first stage was carried out when the plant was 7 days after planting (daps) as much as 2.61 g urea per plant and 1.42 g KCl per-plant. The rest, 5.23 g urea per plant, and 2.85 g KCl per plant were applied 30 daps.

Data analysis

Experimental design

The research used a split-plot design, repeated 3 times. The percentage of para-net shade: 0% (no shade), 25% shade, 50% shade, and 75% shade placed on the main plot. Meanwhile, the various varieties: Sweet Charlie variety, California variety, and Earlibrite variety were placed in sub-plots. The size of each plot is 5.04 m^2, which is divided into 2.1 m in length and 2.4 m in width. Each plot contained 42 planting holes and one plant per planting hole. The 5% level F test was used to determine the interaction or significant effect of the treatment. While the 5% Honestly Significant Difference (HSD) test was used to determine the difference between treatments. Regression analysis is used to evaluate the relationship between two or more variables observed.

Data collection

The data collection is grouped into two parts, the first is about observing the microenvironment of plants, and the second is about observing the growth and harvest parameters.

Table 1. The dose of N, P, and K fertilizer that must be applied

Source of fertilizer	**The dosage of fertilizer applied**		
	kg N ha^{-1} (kg Urea ha^{-1})	**kg N/plot (kg Urea/plot)**	**g N/plant (g urea/plant)**
N	303.44	0.153	
(Urea)	659.65	0.34	8.09
P_2O_5	350	0.17	
(SP_{36})	972.22	0.47	11.24
K_2O	215	0.11	
(KCl)	358.33	0.18	4.37

Micro-environment of plants

Microenvironmental observations of plants were carried out periodically when the plants were 10 days after planting (daps), 22 daps, 34 daps, and 46 daps, including measurements of solar radiation intensity, minimum air temperature, and maximum soil humidity. This observation is based on plant growth phases, namely the initial phase of plant growth as represented by the age of 10 daps, the fast growth phase as represented by the 22 daps of observation age, the peak vegetative phase as represented by 34 daps of observation age, and the reproductive phase as represented by the observation age 46 daps. Each parameter was repeated 3 times, both for plant observations and the plant microenvironment which was carried out randomly.

Radiation intensity

The intensity of solar radiation was measured using a digital Lux meter type AMTAST LX 1332B that was placed under the shade at a height of 1.5 m above ground level. Measurements are made every 11.00 am with the consideration that the sun's rays have formed an angle of 75° with the assumption that the sun rises at 0.6.00 am. The determination of the angle of incidence of the light is in line with the opinion of Rosenberg (1974) which states that the earth rotates at an essentially constant rate, so the rational basis for recording time is as follows: 360°/ 24 h = 15°C/h. In addition, the plant's need for light is not only determined by quantity but also by quality. Measurement of light intensity which was carried out at an angle of incidence of 90°, at 12 am to be precise, caused the quantity and quality of light to begin to decrease due to the low level of transparency of the atmosphere.

Minimum air temperature

The minimum air temperature is observed every 5 o'clock by using an alcohol thermometer. The thermometer was placed in the center of the experimental plot under the shade by hanging it using a raffia rope at a height of 1.5 m from the ground surface.

Maximum soil humidity

Maximum soil humidity was observed every 05.00 am using the Soil Moisturizer Tester type VT05. Measurements are made by pressing the button on the tool before it is plugged into the ground. The soil moisture tester is plugged into the soil to a depth of about 15 cm for a few minutes until the numbers on the tool have not changed, then recorded

Growth parameters

Observation of growth parameters consisting of the number of leaves and surface area of leaves was carried out when the plants were 12 days after planting (daps), 24 daps, 36 daps, and 48 daps. While harvest observations are carried out periodically, starting when the plants are 65 to 90 daps (3 times the harvest period).

Number of leaves, with the criteria of fully formed leaves, excluding young leaves, and leaves that have experienced senescence.

Leaf surface area

Leaf surface area was measured using a Leaf area meter type LI-3100 C for leaves that were fully opened, excluding young leaves and leaves that had experienced senescence. Leaf samples were placed on a glass lens in a position not overlapping or folded. The recording was carried out for all leaf samples from three sample plants per treatment, then averaged. The value of the leaf surface area is determined by multiplying the average value of the recording results by a correction factor. The correction factor can be found by dividing the actual paper area (e.g., 100 cm^2) by the paper area that has been measured using a leaf area meter (e.g., 75 cm^2), so the correction factor is 0.75.

Harvest: *The Weight of Fruit Per Hectare* (WFPH) is obtained by converting fruit weight per harvest plot (5.04 m^2) to hectares using equation 2 (Suminarti et al. 2020).

$$\text{WFPH} = \frac{\text{1 hectare land area}}{\text{harvest plot area}} \text{ X weight of fruit per harvest plot}$$

RESULTS AND DISCUSSION

Microenvironment of plants

Radiation intensity

There was no significant interaction between shade levels and varieties in observing the light intensity. The radiation intensity is only affected by the level of shade (Table 2). This table shows that the highest solar radiation intensity at all ages of observation was obtained in the treatment without shade, each of 719.33 µmol $m^{-2}s^{-1}$ for 12 daps of observation, 1366.0 µmol $m^{-2}s^{-1}$ for 24 daps, 394.66 µmol $m^{-2}s^{-1}$ for 36 daps of observation, and 884.66 µmol $m^{-2}s^{-1}$ for 48 daps of observation. The high value is due to the direct contact between the sun and the surface. However, in the shading treatment, the intensity of radiation received by the surface under the shade showed a proportional decrease with the percentage of shade applied, and the lowest value was obtained at 75% shading for all ages of observation, each of 200.77 µmol $m^{-2}s^{-1}$, 334.0 µmol $m^{-2}s^{-1}$, 112.11 µmol $m^{-2}s^{-1}$, and 279.55 µmol $m^{-2}s^{-1}$. The low value is due to the high level of obstruction (75%) through which sunlight reaches a surface in the shade. Consequently, the radiant energy that will reach the surface under the shade is only 25% of the total incident radiation. The results of Suminarti et al. (2020) also found that in the no-shade treatment (control) the intensity of solar radiation received by the surface was 1503.17 cal cm^{-2} day^{-1}, and this value was much higher by 20% (300.84 cal cm^{-2} day^{-1}), 66% (597.75 cal cm^{-2} day^{-1}), and 149.70% (901.17 cal cm^{-2} day^{-1}) respectively for 25% shading, 50% shading, and 75 % shading. While the treatment of varieties has no significant effect on the reception of solar radiation energy because there is no direct effect of varieties on the reception of solar energy.

Minimum air temperature

Analysis of variance showed that there was no interaction or significant effect of the treatment on the observation of the minimum air temperature at various ages of observation (Table 3).

It is known that the minimum air temperature describes the condition of the lowest air temperature, occurring at night, around 03.00 in the morning. In the treatment without shade, a surface will experience direct contact with the sun, resulting in high available energy on the surface. Considering that this earth will act as “Black Body radiation”, the energy that has been absorbed during the day will be released back into the atmosphere until the sun sets (Mubarak et al. 2018). As a result, the available energy on the surface continues to decrease until a minimum temperature is formed. While in the shading treatment, the magnitude of the shade level will be a barrier to receiving solar radiation energy on a surface under the shade. The greater the level of obstruction (75% shading), the lower the energy received by the surface (Mubarak et al. 2018). However, considering that the color of the shade of the para-net is black, and because this black color can absorb more energy than other colors, it causes the available energy on the surface under the shade to increase. As a result, the minimum air temperature achieved in the shaded treatment was almost the same as in the non-shaded treatment. This is what causes no significant effect of shading on the minimum air temperature produced. This information is in line with the results of research by Ruberti et al. (2012) who found that there was no significant effect of the shading treatment on the air temperature produced. In the treatment without shade, as well as with 55% and 75% shade, the average air temperature produced was 25.5°C, 26.5°C, and 26.15°C respectively. Table 3 also shows that there is no significant effect of the varieties on the formation of minimum air temperature. This is because the measurement of the minimum air temperature is carried out 1 meter above the strawberry plant canopy, so there is no significant effect from the strawberry plant on the formation of the minimum air temperature.

Maximum soil moisture

The interaction between shade treatment and varieties did not occur at the maximum soil moisture observations. Maximum soil moisture is only affected by the percentage of shade used (Table 4).

Table 4 shows that the lowest maximum soil moisture was generally obtained in the treatment without para-net shade, an average of around 61.11%. While the higher was obtained in the treatment with 50% and 75% para-net shade, respectively 70.83% and 73.26%. It is known that the level of soil moisture produced is strongly influenced by the level of available radiation energy on the surface. At low radiation intensities, the soil moisture value remains high as a result of the low rate of water loss from the soil through the evaporation process (Suminarti et al. 2021). However, when the energy available at the soil surface is high, the rate of evaporation will take place quickly which results in a high rate of water loss from the soil, and results in a low soil moisture value (Shi et al. 2016). The results of research on the intensity of solar radiation showed that in the treatment without shade, the radiation energy received by the surface was the highest with an average of 841.63 µmol $m^{-2}s^{-1}$, and this value indicated a decrease with the application of the shade treatment. The reduction was respectively 148.40% (502.81 µmol $m^{-2}s^{-1}$) for 25% shading, 184.89% (546.21 µmol $m^{-2}s^{-1}$) for 50% shading, and 263.38% (610.02 µmol $m^{-2}s^{-1}$) for 75 % shading (Table 2). This is what causes the significant effect of the shading treatment on the resulting maximum soil moisture. These results are in line with the results of Polthanee et al. (2011) who found that the highest soil moisture was obtained in the 75% shading treatment, which was 57.67%, and the lowest was obtained in the no-shaded treatment, which was 50.33%. Meanwhile, there was no significant effect of the varieties’ treatment on maximum soil moisture as a result of the absence of a significant effect of the variety on the intensity of solar radiation (Table 2), as well as the minimum temperature produced (Table 3). While the two environmental elements are the main factors that influence the formation of soil moisture.

Table 2. The average intensity of solar radiation at four levels of para-net shading and three varieties at four observation ages

Treatment	The average intensity of solar radiation at four levels of para-net shading and three varieties (µmol $m^{-2}s^{-1}$) at four observation ages (dap)			
	10	**22**	**34**	**46**
Para-net shading rate (%)				
0 (Without shade)	719.33 d	1366.0 d	394.66 c	884.66 d
25	356.67 c	541.55 c	146.0 b	448.44 c
50	269.67 b	431.67 b	120.66ab	359.66 b
75	200.77 a	334.0 a	112,11 a	279.55 a
HSD 5%	37.78	56.74	33.23	29.62
Kinds of varieties				
Sweet Charlie	383.17	674.41	194.33	496.0
California	389.26	668.67	194.91	496.16
Earlibrite	387.0	659.83	190.83	487.08
HSD 5%	ns	ns	ns	ns
SD	6.12	14.68	8.05	21.10

Note: Numbers accompanied by the same letter in the same treatment and column are not significantly different by HSD 5% test. Dap: Days after planting; ns: no significant effect; HSD: Honestly Significant Difference; SD: Standard Deviation

Table 3. The average minimum air temperature at four levels of para-net shade and three strawberry varieties at four observation ages

Treatment	The average minimum air temperature (°C) at four observation ages (dap)			
	10	**22**	**34**	**46**
Para-net shading rate (%)				
0 (Without shade)	23.0	21.0	21.0	21.0
25	22.67	20.67	20.89	21.0
50	22.33	20.33	20.67	20.67
75	22.0	20.0	20.55	20.55
HSD 5%	ns	ns	ns	ns
Kinds of varieties				
Sweet Charlie	22.50	20.50	20.83	20.83
California	22.50	20.50	20.67	20.75
Earlibrite	22.50	20.50	20.83	20.83
HSD 5%	ns	ns	ns	ns
SD	0.1	0.1	0.22	0.14

Note: ns: no significant effect; Dap: Days after planting; HSD: Honestly Significant Difference; SD: Standard Deviation

Growth parameters

Number of leaves

Analysis of variance showed that there was no significant interaction between shade treatment and variety in leaf number. The number of leaves was only affected by the variety that occurred at the age of 36 and 48 days after planting (daps) (Table 5).

There was no significant effect of the shade treatment on the number of leaves variable due to the formation of a higher minimum temperature in the treatment, ranging from 21°C to 23°C (Table 3) at various levels of shade. While the average air temperature desired by strawberry plants is only around 17°C-20°C. Temperature is one of the elements of climate that has a major influence on the physiological processes of plants. At high temperatures (especially minimum temperatures), it can stimulate an increase in the respiration process, while respiration is a process of catabolism (breaking down) of the energy that has been formed (sugar) into growth energy in the form of carbon dioxide (CO_2) and water (H_2O) (Liu et al. 2014). In addition, high temperatures will also disrupt the process of transporting and spreading assimilation from photosynthetic sources (leaves) to the meristematic parts (Hossain et al. 2018). This will then have an impact on disrupting the processes of division, elongation, and dilation of cells, which in turn will have an impact on inhibiting the process of plant growth, including the process of leaf formation. Considering that the minimum temperature formed in the various shading treatments is above the average requirement of the strawberry plant, it will have the same effect on physiological disturbances (leaf formation). This is what causes no effect of the shading treatment on the number of leaves variable. In the variety treatment, it was found that the highest number of leaves was produced by the California variety, while the lowest was found in the Earlibrite variety. The occurrence of these differences is a result of the different characters of each variety.

Leaf surface area

Table 6 shows that the leaf surface area is only affected by the shade treatment. The effect of variety and the interaction between shade and variety does not occur in these variables.

In the shade treatment, the widest leaves were found in the 75% shade treatment, with an average area of 270.04 cm^2, compared to the treatment without shade which only reached 194.76 cm^2. The increase in leaf area in the 75% shade treatment is a form of plant adaptation in an effort to efficiently capture light energy for photosynthesis normally under low light intensity conditions (Kobayashi et al. 2011). In addition, plants that are grown in shaded conditions (low intensity) have thinner cuticles, so the leaves that are formed are also thinner. Liu et al. (2020) also stated that in plants grown in shaded conditions, chloroplasts are composed evenly between the two layers of the mesophyll; palisade and sponge to increase efficiency in capturing light radiation energy for the photosynthesis process. The results of the study by Islam et al. (2020) also found that the chlorophyll-b content in plants that were 50% shaded was higher, which was 69.8 mg g^{-1} when compared to plants that were not shaded which only reached a value of 46.8 mg g^{-1}. It becomes important, especially for plants that are grown in shaded conditions because chlorophyll-b acts as a photosynthetic antenna that functions as a light collector (Wang et al. 2013). However, in plants that are not shaded, the leaves that are formed are thicker because they have thick cuticles, but are narrower due to suppressing the high rate of transpiration and evapotranspiration. The palisade layer contains 2-3 cellular layers in non-shaded plants (Liu et al. 2020). Table 6 also informs that the leaf surface area is not affected by the variety of treatments. Morphologically, the three varieties have almost the same size of leaf area, so statistically, they have not been able to show their effect.

Table 4. Average maximum soil moisture at four levels of para-net shade and three strawberry varieties at four observation ages

Treatment	The average maximum soil moisture (%) at four observation ages (dap)			
	10	22	34	46
Para-net shading rate (%)				
0 (Without shade)	65.97 a	63.19 a	57.63 a	57.65 a
25	77.77 b	64.58 a	64.58 b	65.27 b
50	76.38 b	69.44 b	67.36b c	70.13 c
75	81.25 c	70.83 b	70.13 c	70.83 c
HSD 5%	3.29	2.68	3.29	4.30
SD	6.04	4.92	6.04	7,91
Kinds of varieties				
Sweet Charlie	73.95	68.22	64.06	66.15
California	76.04	66.67	67.18	66.15
Earlibrite	76.04	66.14	63.54	65.62
HSD 5%	ns	ns	ns	ns

Note: Numbers accompanied by the same letter in the same treatment and column are not significantly different by HSD 5% test. Dap: Days after planting; ns: no significant effect; HSD: Honestly Significant Difference; SD: standard deviation

Table 5. The average number of leaves at four levels of para-net shade and three strawberry varieties at four observation ages

Treatment	The average number of leaves (leaves) at four observation ages (dap)			
	12	24	36	48
Para-net shading rate (%)				
0 (Without shade)	3.83	3.62	5.77	6.83
25	3.72	3.45	5.61	6.94
50	3.94	3.62	5.88	7.00
75	4.11	3.67	6.16	7.67
HSD 5%	ns	ns	ns	ns
SD	0.51	0,92	0.69	0.58
Kinds of varieties				
Sweet Charlie	3.79	4.83	5.83 b	7.12 b
California	4.12	5.16	6.41 c	7.58 c
Earlibrite	3.79	4.37	5.33 a	6.62 a
HSD 5%	ns	ns	0.25	0.23

Note: Numbers accompanied by the same letter in the same treatment and column are not significantly different by HSD 5% test. Dap: Days after planting; ns: no significant effect; HSD: Honestly Significant Differences; SD: Standard Deviation

The total dry weight of the plant

There was a significant interaction between the shade treatment and the variety in measuring the total plant dry weight (Figure 1).

Figure 1 shows that in the treatment without shade, as well as with 25% shade, the highest total dry weight of the plant was found in the California variety, which was 28.04 g/plant and 20.33 g/plant, respectively. The high value is closely related to the higher radiation intensity received by the two treatments, an average of 841.16 µmol $m^{-2}s^{-1}$, and 373.17 µmol $m^{-2}s^{-1}$ (Table 2). Besides that, characteristically, the California variety has a wider leaf surface, which is 253.68 cm^2, and this value is still 14.37% and 13.80% higher when compared to the sweet Charlie and Earlibrite varieties. This is why the total dry weight of plant produced by the California variety was the highest at that shade level when compared to the Sweet Charlie and Earlibrite varieties, which respectively only reached 15.83 g/plant and 13.17 g/plant for the treatment without shade, and 16.23 g/plant and 11.69 g/plant for 25% shade treatment. At 50% shade, the highest total plant dry weight was found in the Sweet Charlie variety (17.0 g/plant), when compared to the California variety (14.26 g/plant), and the Earlibrite variety (13.05 g/plant). Based on the results of the study, it was shown that 50% shading was identical with receiving radiation energy of 295.42 µmol $m^{-2}s^{-1}$, while the energy requirements for the California variety ranged from 373.17 - 841.16 µmol $m^{-2}s^{-1}$ (Table 2). The impact of this low energy is the less-than-optimal physiological activity that occurs in the California variety, particularly photosynthetic activity. As a result, the photosynthate produced decreases as the received radiation energy decreases (Table 7). A similar incident occurred in the 75% shade treatment, where the lowest total plant dry weight was also found in the California variety, which was 12.99 g/plant. This is related to the low energy available in the 75% shading treatment which only reached 231.61µmol $m^{-2}s^{-1}$. The amount of energy received is not sufficient to meet the energy needs of the California variety to achieve optimal physiological activity. As a result, the synthesis of carbohydrates is disrupted which causes a lower total plant dry weight produced.

The weight of fruit per hectare (WFPH)

There was a significant interaction between shade treatment and variety on fruit weight per hectare (Figure 2).

Figure 2 shows that in the treatment without shade or with 25% shade, the highest fruit weight per hectare was found in the California variety, which was 1.06 t ha^{-1} and 0.80 t ha^{-1}. While the lowest was found in the Earlibrite variety, each of 0.34 t ha^{-1} and 0.27 t ha^{-1}. The high fruit weight of the California variety was closely related to the high photosynthate produced by the plants which can be described by measuring the total plant dry weight, respectively 28.04 g/plant for the no-shade treatment, and 20.33 g/plant for the treatment 25% shade (Table 7). The results of the regression analysis proved that there was a strong linear relationship between shade (X) and fruit weight per hectare (Y) for the California variety given by the equation: $Y = - 105.2 X + 103.7$; $R^2 = 0.94$*. This equation means that the weight of fruit per hectare produced is 94% affected by the percentage of shade. The higher the shade percentage, the lower the fruit weight per hectare it produces. At 50% and 75 % shade, the highest fruit weight per hectare was found in the Sweet Charlie variety, which was 0.66 t ha^{-1}, while the lower was found in the California variety and the Earlibrite variety, each of 0.39 t ha^{-1}, and 0.34 t ha^{-1}. The low yield of the two varieties was due to the low available radiation intensity for the California variety, because this variety is tolerant to high intensities (373.17-841.16 µmol $m^{-2}s^{-1}$). Whereas the Earlibrite variety is very tolerant to low light intensity reception (231.61-431,19 µmol $m^{-2}s^{-1}$) and sensitive to high radiation intensity reception. Based on the observations (Table 2), it was found that 75% shading is identical to 231.61 µmol m^{-2}s-^{1}, and 50% is identical to 295.41 µmol $m^{-2}s^{-1}$, so 50% shading is a condition that is not suitable for the process of growth and development of California and Earlibrite varieties.

Table 6. Average leaf area surface at four levels of para-net shade and three strawberry varieties at four observation age

Treatment	The average leaf area surface (cm^2) at four observation ages (dap)			
	12	24	36	48
Para-net shading rate (%)				
0 (Without shade)	142.25 a	185.67 a	215.58 a	235.55 a
25	161.42 a	218.28 b	236.97 b	270.74 b
50	200.60 b	238.43 bc	257.37 c	290.11 b
75	226.27 c	251,89 c	278.37 d	323.61 c
HSD 5%	25.73	32.61	20.39	33.37
Kinds of varieties				
Sweet Charlie	192.69	218.51	233.56	242.48
California	199.77	223.82	240.07	351.04
Earlibrite	189.01	215.09	237.99	249.56
HSD 5%	ns	ns	ns	ns

Note: Numbers accompanied by the same letter in the same treatment and column are not significantly different by HSD 5% test. Dap: Days after planting; ns: no significant effect; HSD: Honestly Significant Differences

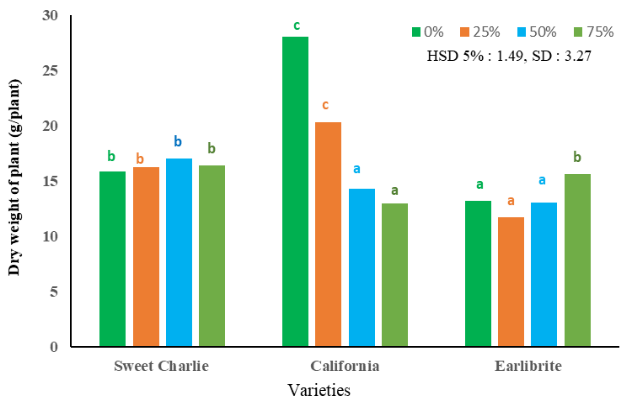

Figure 1. Interaction between shade and variety on total plant dry weight of the plant

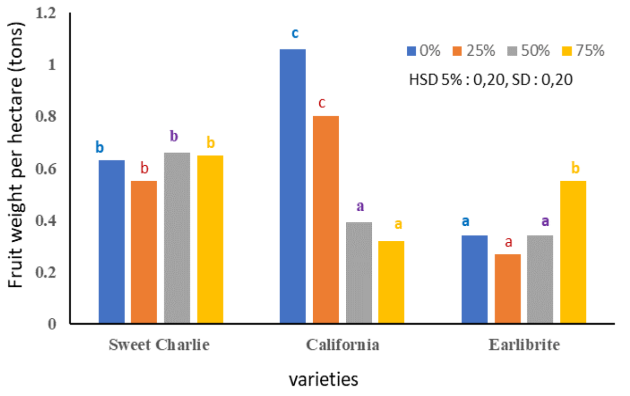

Figure 2. Interaction between shade and variety on fruit weight per hectare

In conclusion, based on the research results, it can be concluded that there is a significant effect of the shading treatment on radiation energy reception, maximum soil moisture, and leaf surface area. Meanwhile, significant interactions only occurred in the measurement of fruit weight per hectare. From these results, it was informed that in the treatment without shade, as well as with 25% shade, the highest fruit weight was found in the California variety, 1.06 t ha^{-1} and 0.80 t ha^{-1}, respectively. Whereas at 50% shade, the highest fruit weight per hectare was found in the Sweet Charlie variety, which was 0.66 t ha^{-1}, and at 75% shade, higher yields were found in the Sweet Charlie variety, as well as the Earlibrite variety, respectively each of 0.65 t ha^{-1} and 0.55 t ha^{-1}. California variety is a fairly tolerant variety to be developed in the Jatikerto area.

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