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Investigation of reflective mulches effect on soybean physiology character at low light intensity

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Abstract

The effort to scale up soybean production is by agro forestry system. However, these conditions give a response to the plants because the light is reduced by the canopy of trees so that affects the plant microclimate and plant physiology. This study aimed to analyze the effect of using reflective mulch to physiology character and soybean production in shaded and not shaded conditions. The efforts to increase the light that reach the plants is by using reflector. The research conducted in Bogor, West Java Indonesia using nested design-two factors model, the first factor had two levels, respectively shade 50% (N50%) and without shade (N0%). The second factor had reflector mulches three levels, respectively black silver mulch (MP-PH), metalic mulch (MP-MA) and without mulch (M0). The results showed that the using of reflective mulch in 50% shade condition were able to give a positive response to physiology and crop production. The using of mulch increased the rate of plants photosynthesis significantly in 50% shade condition 14.52µmol µmol $CO_2.m^{-2}.s^{-1}$ for the black and silver mulch and 18.17µmol $CO_2.m^{-2}.s^{-1}$ for metalic mulch, whereas only 12.61µmol $CO_2.m^{-2}.s^{-1}$ for the control (M0). The increase of photosynthesis rate was positively correlated in the increase of crop yields 4.79 and 4.79 tons/ha respectively for metallic mulch and silver black mulch, whereas 2.93 tons/ha for without mulch in 50% shade condition. In 0% shade condition, the potential yield were 5.17, 4.11, 3.43 tons/ha respectively for silver black mulch, metallic mulch, and without mulch.

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Introduction

Soybean is one crop that is widely consumed and modified into some processed foods such as soy sauce and soy milk. Type of these processed soybean material is quite popular among Asian because soybean has high nutrient content. Soybeas contains water, protein, fat, fiber, sugar, vitamin E and other essential substances. These contents make soybeans into a distinguished commodity in several countries, and its productivity is continuously increased.

World soybean production in 2015 were up to 315.86 million tons, where the country with the largest production was American followed by Brazil and Argentina. Soybean production in Indonesia in 2015 approximately around 982.97 thousand tons of dry beans, increased by 27.97 thousand tons (2.93%) than in 2014 (BPS, 2015). One way to increase soybean production is by expanding the planting area. It could be done by utilizing lands such as land under the canopy of tree crops or agro forestry. This utilization could be done anywhere, but the shade reduced the sunlight so that the radiation that reach the plant is also reduced. These conditions give a response to the plants such as morphology and physiology response, and crop production.

Manurung *et al.* (2008), Muhuria (2007) stated that agroforestry system cause low light stress, resulting in lower crop production by 26.6% compared with full light condition. This is due to a mismatch in microclimate such as temperature and humidity caused by low light intensity. Besides, the sunlight which reduced by the shade also cause a decrease in plant dry susbtance, reduced the number and percentage of the open stomata and caused the leaf to be thin (Jufri, 2006).

The sunlight also affects the rate of plant respiration. At full light intensity, the rate of photosynthesis and respiration ate high so that the effect of light is an indirect influence toward respiration. Respiration is closely related to temperature, if the temperature increases, the respiration rate will increase (June, 2002).

Because of the importance of light for the plants, an effort to increase the efficiency in taking sunlight in shaded conditions is required.

This attemps is performed by utilizing the radiation that reach the surface (transmitting radiation) to be reflected back to the plant Used reflective mulch. Mejias (2012) and Meyer (2012) discovered that the using of reflective mulch in plants could give positive response to the yield and quality of crops. Plants in low light have different physiological and production mechanisms because microclimate incompatibility.

Therefore research on physiological responses is needed to understand the mechanism of plant physiological characteristics of the use of reflective mulch that adds radiation to plants through the albedo process. So the aim of the research to analyze the effect of reflective mulch to physiology character and soybean crop production at low light intensity.

Materials and methods

Time and Place

This study was conducted in an area in Situgede, Bogor, West Java, from October 2016 until January 2017. Measurement of equipment preparation were performed at Meteorological Instrumentation Laboratory, samples processing were conducted at Agro meteorology Laboratory, Integrated Laboratory and Micro technique Laboratory Agronomy and horticulture Department.

Materials

Materials used in this study is the soybean plant seed Anjasmoro variety. The tools used in this study consists of a data logger, radiation sensor solarimeter, Licor 6400, trinocular microscope, Olympus BX41 microscope (electric), tools for cultivating plants and other equipments. Radiation inhibitor (paranet) 50% and reflector made of mulch were used to modificate microclimate. Application software used SAS 9.0, Adobe Photoshop CS6 and DP2-BSW.

Methods and Statistical analysis.

This study was microclimate modification on soybean plants by giving radiation inhibitor using reflector paranet and reflector which was used to reflect the sunlight back to the plants. These modifications provide a characteristics of simulation of the radiation scale and its effects on soybean which were arranged in Nested Design two factors.

The first factor was shade paranet with two levels i.e. without shade (N0%) and 50% shade (N50%) condition, and the second factor was the use of mulch as a radiation reflector consist of three levels i.e. without mulch reflector (M0), silver black mulch (MP-PH) and metallic mulch (MP-MA).

Observation component including of physiological component and plant production.Data were analyzed statistically by analysis of variance (ANOVA) and tested with Duncan Multiple Range Test (DMRT) with 95% confidence interval using SAS 9.0.

Results and discussion

The combined analysis of variance of physiology character in Table 1 showed that reflective mulch and shade significantly affect the number of stomata, stomatal density, the percentage of open stomata, leaf thickness and photosynthesis rate. Besides the interaction of mulch on the shade (NxM) significantly affected the number of stomata, stomatal density, leaf thickness and photosynthesis rate.

Table 1. Analysis of variance effect of shade (N), mulch (M) and interaction (NxM) of physiological character.

Observation variables	Shade (N)	Reflective Mulch (M)	Interaction (NxM)
Number of stomata	.008*	.007*	.002*
Stomatal density	.002*	.023*	.001*
Percentage of open stomata	.002*	.038*	.160
Stomatal conductance	.316	.053	.699
Leaf thickness	.003*	.017*	.037*
Leaf chlorophyll (SPAD)	.016*	.006*	.436
Photosynthesis rate	.003*	.002*	.003*

*) significance level P≤0.05.

Number, Density and Percentage of Open Stomata

Variables number and density of stomata in Table 2 generally influenced significantly by the presence of shade and mulch treatment. The effect of shade significantly reduced the number and density of stomata in each mulch treatment. The decrease was influenced by the reduction of radiation up to the leaf so that the leaf become wider, and affect the density of stomata observed under a microscope at 40x magnification with a field number of 0.19625mm².

Table 2. Mean of DMRT (Duncan's Multiple Range Test) treatment interaction to the number of stomata and stomata density.

Observation variables	Without Shade $\bar{X}$ ± SD		50% Shade $\bar{X}$ ± SD		Alteration Percentage
Number of stomata					
silver black mulch	53.84 ± 0.146	e	42.24 ± 0.723	a	21.55%
metallic mulch	52.29 ± 1.028	d	43.70 ± 1.327	b	16.43%
without mulch	52.00 ± 0.928	d	41.54 ± 0.378	a	20.12%
Stomatal density (mm²)					
silver black mulch	274.31 ± 0.745	e	215.20 ± 1.628	a	21.55%
metallic mulch	266.44 ± 5.239	d	221.01 ± 1.666	b	15.92%
without mulch	251.32 ± 4.727	c	211.62 ± 1.925	a	15.80%

The letters in each row ad column showed no significant difference based on DMRT at α = 5 %. Without shade (N0%), 50% shade (N50%).

The use of reflective mulch in two shade conditions showed theinteraction of the number of stomata and stomatal density. Reflective mulch treatment showed the tendency of increasing in the number of stomata on different shade levels.

The percentage of open stomata which was presented in Fig. 1 did not show any significant difference to development phase. The average percentage of open stomata in 0% shade condition in both phases was around 80%, where silver black mulch tends to have higher percentage.

In 50% shade condition, the percentage of open stomata approximately 60%, where metallic mulch tends to have higher percentage. The decrease of percentage in 50% shade condition was related to stomatal density and the number of stomata where the percentage of stomata open was the ratio between the number of open stomata with total number of stomata on a particular point of view.

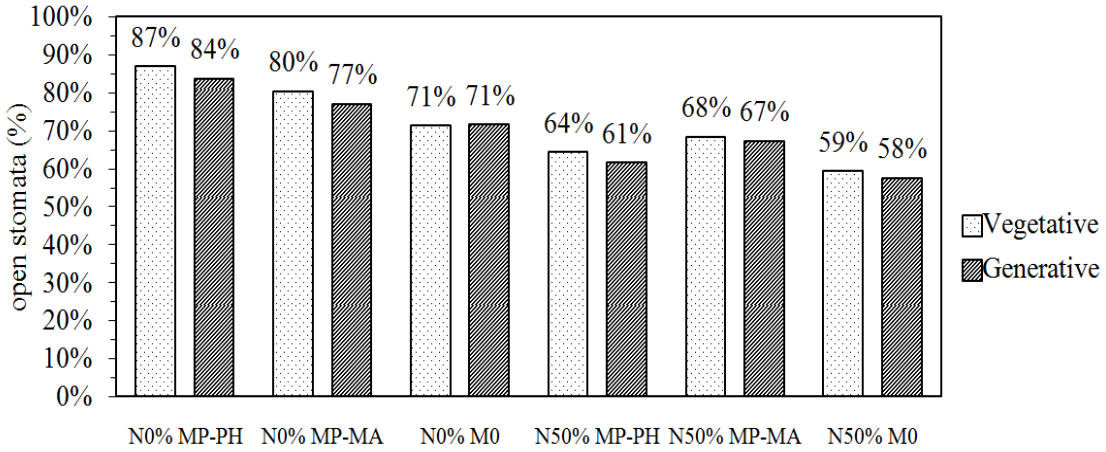

Fig. 1. Percentage of open stomata. Without shade (N0%), 50% shade (N50%), silver black mulch (MP-PH), metalllic mulch (MP-MA) dan without mulch (M0).

Soybean was sensitive to shade, causing the changes in physiological characteristics such as stomata and the opening of stomata Muhuria (2007) and Jufri (2006). Lersten and Carlson (1987) stated that stomata was associated with the exchange of CO_2 gas into the materials for photosynthesis. The more and wider the opening, the higher stomatal conductivity so that the higher the CO_2 exchange.

Leaf thickness and chlorophyill

Analysis of variance in Table 1 showed that the use of reflective mulch and shade significantly influence the thickness of the leaf. The presence of mulch treatment were able to provide a significant difference in each shade (Table 3).

The use of mulch in 50% shade condition have not been able to reach normal conditions but the use of mulch tends to increase leaf thickness. metallic mulch showed the highest leaf thickness in 50% shade condition as well as in without shade (N0%) condition. The increase of leaf thickness was positively correlated to the production of dry weight of plant leaves.

Table 3. Mean of DMRT (Duncan's Multiple Range Test) to leaf thickness and chlorophyll.

Observation Variables	Without Shade		50% Shade		Alteration Percentage
	$\bar{X}$ ± SD		$\bar{X}$ ± SD		
Leaf thickness (µm)					
silver black mulch	200.02 ± 3.976	d	157.31 ± 2.195	a	28.50%
metallic mulch	222.16 ± 1.691	c	168.13 ± 3.006	b	26.12%
without mulch	194.89 ± 3.793	d	160.61 ± 1.224	b	13.48%
Relative leaf chlorophyll (SPAD)					
silver black mulch	46.98 ± 1.501	c	42.70 ± 0.312	ab	9.11%
metallic mulch	46.27 ± 1.877	c	42.60 ± 0.327	ab	7.92%
without mulch	43.13 ± 1.544	b	40.70 ± 1.033	a	5.64%

The letters in each row ad column showed no significant difference based on DMRT at α = 5 %. Without shade (N0%), 50% shade (N50%).

The increase of leaf thickness in metallic mulch and 0% shade condition was the adaptation of plant against high temperature because this kind of mulch reflect more radiation, consequently the plants had an adaptation against the increase of temperature by increasing the leaf thickness. Epidermis part of soybean leaves contained fur or trichomes where these trichomes had ecological functions such as reducing evaporation by protecting stomata from high temperature by increasing the leaf thickness and decreasing transpiration (Velasco *et al.* 2001).

Soybeans grown in full light condition (without a shade factor) had more than one palisade layer so that the leaf became thicker whereas in 50% shade condition there was only a single layer, that was the reason the leaf became thinner (Khumaida, 2002).

Relative leaf chlorophyll content of soybean leaf in units showed that relative leaf chlorophyll content tends to be higher in 0% shade condition compared with 50% shade condition, either in vegetative phase or in generative phase. The increase in chlorophyll was closely related to the acceptance and use of radiation by plant.

Photosynthesis Rate and Stomatal Conductance

Analysis of variance showed that shade and mulch gave effect to the interaction of photosynthetic rate of soybean plants (table 4). Shade significantly effect in decreasing photosynthesis rate in each mulch treatment where photosynthesis rate of 0% shade condition was around 21.74 µmol $CO_2.m^{-2}.s^{-1}$, while in 50% shade condition was around 15.09µmol $CO_2m^{-2}.s^{-1}$. Although the use of mulch in 0% shade condition did not show significant different based on Duncan's Multiple Range Test α = 5%, but in 50% shade condition, mulch showed a significantly different effect for each type of mulch.

Table 4. Mean of DMRT (*Duncan's Multiple Range Test*) interaction of treatmen to photosynthesis rate and stomatal conductance.

Observation Variables	Without Shade $\bar{X}$ ± SD		50% Shade $\bar{X}$ ± SD		Alteration Percentage
Photosynthesis rate (µmol CO2.m^{-2}.s^{-1})					
silver black mulch	21.74 ± 0.702	d	14.52 ± 0.615	b	33.22%
metallic mulch	21.85 ± 0.617	d	18.17 ± 1.280	c	16.84%
without mulch	21.65 ± 0.663	d	12.61 ± 0.759	a	41.76%
Stomata conductance (µmol H2O.m^{-2}.s^{-1})					
silver black mulch	0.057 ± 0.004	b	0.056 ± 0.001	ab	0.76%
metallic mulch	0.058 ± 0.002	b	0.057 ± 0.001	b	1.40%
without mulch	0.055 ± 0.001	ab	0.052 ± 0.002	a	5.09%

The letters in each row ad column showed no significant difference based on DMRT at α = 5 %. Without shade (N0%), 50% shade (N50%).

Stomatal conductance also showed a tendency to alter stomatal conductance in two shade conditions with each type of mulch. The use of mulch in 50% shade condition were able to increase stomatal conductance approaching normal conditions i.e. in 0% shade condition and was better than plants without mulch treatment under normal condition.

The Relation of Leaf Temperature and Photosynthesis rate

The use of mulch in each shade showed effect on microclimate of plant so that it also could affect plant. One element that effect climate is temperature.

Response of soybean against temperature showed in plant physiological in each shade. Based on the results, a significant

Difference of temperature could be seen in each shade. This difference of temperature gave a different effect on photosynthesis rate

So that the relation between temperature and photosynthesis rate could be obtained.

Table 5. Mean of DMRT (*Duncan's Multiple Range Test*) in traction of treatment to leaf temperature (°C) and performance of mulch reflectance.

Observation variable	Without Shade		50% Shade	
	$\bar{X}$ ± SD		$\bar{X}$ ± SD	
Temeperature (°C)				
silver black mulch	29.53 ± 0.223	d	28.08 ± 0.223	b
metallic mulch	29.16 ± 0.112	d	28.45 ± 0.038	c
without mulch	29.01 ± 0.059	d	27.77 ± 0.251	a
Performance of mulch reflectance (%)				
silver black mulch	25.89 ± 1.063	c	13.15 ± 0.650	b
metallic mulch	33.90 ± 1.045	b	19.08 ± 1.458	c
without mulch	7.80 ± 0.740	a	6.92 ± 0.740	a

The letters in each row ad column showed no significant difference based on DMRT at α = 5 %. Without shade (No%), 50% shade (N50%).

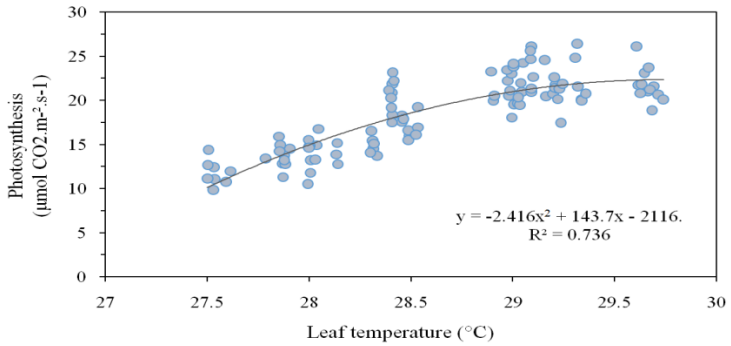

Fig. 2. The relation of leaf temperature and photosynthesis rate.

Fig. 2 showed that temperature was positively correlated to photosynthesis rate of soybean, where the rise of temperature was followed by the increase of photosynthesis rate. But this relation had a quadratic pattern, which means photosynthesis rate would reach a certain point at the optimum temperature but would eventually decrease. Quadratic regression graph of the effect of temperature on photosynthesis rate showed regression value of R^2 = 0.7364. Temperature is one of environmental factors that could affect photosynthesis rate (Ribeiro *et al.* 2006).

In 50% shade condition, the potential yield were 4.79 and 4.27 tons/ha respectively for metallic mulch and silver black mulch, whereas the potential yield for without mulch treatmen was up to 2.93 tons/ha. In 50% shade condition, the potential yield were 5.17, 4.11, 3.43 respectively for metallic mulch, silver black mulch, and without mulch.

Table 6. Mean of DMRT (Duncan's Multiple Range Test) interaction of treatment to production variables.

Observation variables	Without Shade		50% Shade	
	$\bar{X}$ ± SD		$\bar{X}$ ± SD	
Number of pea per plant				
silver black mulch	97.30 ± 5.927	c	79.67 ± 5.281	b
metallic mulch	77.30 ± 4.444	b	89.67 ± 2.367	c
without mulch	67.96 ± 1.869	a	64.43 ± 4.571	a
Production (ton/ha)				
silver black mulch	5.17 ± 2.611	d	4.27 ± 2.223	bc
metallic mulch	4.11 ± 0.568	b	4.79 ± 0.750	cd
without mulch	3.43 ± 0.721	a	2.93 ± 0.814	a

The letters in each row ad column showed no significant difference based on DMRT at α = 5 %. Without shade (No%), 50% shade (N50%).

Conclusions

The use of mulch significantly increased photosynthesis rate in 50% shade condition i.e. 14.52µmol $CO_2.m^{-2}.s^{-1}$ for silver black mulch and 18.17µmol $CO_2.m^{-2}.s^{-1}$ for metallic mulch, whereas photosynthesis rate of control (did not use mulch) was only 12.61µmol $CO_2.m^{-2}.s^{-1}$. The increase of photosynthesis rate was positively correlated to the increase crop yields i.e. 4.79 and 4.27 tons/ha respectively for metallic mulch and silver black mulch, whereas the crop yields without mulch was 2.93 tons/ha in 50% shade condition and In 0% shade condition, the potential yield of silver black mulch, metallic mulch, and without mulch were 5.17, 4.11, 3.43 respectively.

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