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Soybean Varieties Respond to the Shade of Teak Trees

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ABSTRACT

Background: Light is one of the environmental factors that greatly affect the growth and yield of crops in general, including soybean plants. The purpose of this study was to determine the effect of shade on yield and yield components of soybean varieties

Methods: The research method was a randomized complete block design (RCBD) with three replications. The first factor was the kind of variety which consisted of two levels, i.e., Dena I and Anjasmara. The second factor was the level of shading, which consisted of four levels, i.e., 0, 10-20, 20-30, and 30-40%.

Result: The results showed that shade decreased the number of filled pods, dry pod weight per plant, 100 seeds weight, and seed yield ha^{-1}. As the shade increases, the lower the yield and component of soybean yields increases.The decrease in seed yield ha^{-1} of Dena I variety at 10-20, 20-30, and 30-40% shade was 22, 14, and 50%, respectively, while the Anjasmara variety was 9, 49, and 59%. Shade decreases yields and yield components of Dena I and Anjasmara varieties. In the higher level of shade, the yield reduction will increase.

Keywords: Response, Shading, Soybean, Variety, Yield

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INTRODUCTION

Solar radiation is one of the most important abiotic factors for agricultural production (Liu *et al*. 2018). A slight increase or decrease in light intensity for most plants will cause large changes in the photosynthesis process (Wu *et al*. 2017). Light intensity affects important plant processes such as physiology, biochemistry, and cell division (Wu *et al*. 2018). Many processes in plants are disrupted by a decrease in light intensity which brings about dramatic developmental and physiological changes, leading to a rapid decline of these processes (Wu *et al*. 2016). Shades can affect the carbon balance of plants because the demand for carbohydrates (sugar) increases while production decreases: the rate of physiological processes increases while the yield of photosynthesis decreases (Yang *et al*. 2018)). Thus, tolerance to shade stress is reduced at low photosynthetic rates in C_3 plants (Su *et al*. 2014). In addition, the carbohydrate (sugar) pattern becomes an expensive process, as structural protein biosynthesis (especially chlorophyll protein) increases with increasing shade (Yang *et al*. 2018). The rate of photosynthesis is the main driver of plant carbon balance, optimal and sustainable light availability should also be considered to study the response of plants to shade stress.

The response of plants to a shaded environment is determined by their tolerance to reduced light intensity. One of the effects of shade on plant morphology is that the plant stems become taller because the plant stems are etiolated (Dhariwal *et al*. 1998). This morphological condition causes the plants to fall easily so that they can reduce the yield of seeds. The shade of 50% during growth resulted in a decrease in soybean seed yields of between 37 and 74% (Steppuhn *et al*. 2005), and in rice resulted in a decrease in the yield of more than 55% (Sulistiyono *et al*. 2002). Another effect of shade on plant morphology is an increase in leaf area (Kisman *et al*. 2007) which aims to make light absorption more efficient so that the photosynthesis process can run normally (Djukri and Purwoko 2003). In the reproductive phase of some soybean varieties, shade stress causes a faster flowering and harvesting age than in an unshaded environment (Rahmanda *et al*. 2017).

By the research of Susanto and Sundari (2011), light reception by soybean plants is different in each environment. The yield of soybean seeds under the shade of maize, cassava, black paranet, and optimal environment were 0.35, 0.36, 1.33, and 2.13 tons ha^{-1}, respectively. Sundari and Susanto (2015) reported that up to 75% shade intensity increased plant height and specific leaf area, but reduced leaf number and area, light absorption rate, photosynthesis rate, leaf chlorophyll index, number of filled pods, and seed weight per soybean plant. Each plant genotype has a different tolerance to shade stress. Plants that are adaptive to low radiation have increased leaf area ratios, stem leaf ratios, stem lengths, and decreased leaf thickness (Haque *et al*. 2009). The purpose of this study was to determine the effect of shade on yield and yield components of soybean varieties.

MATERIALS AND METHODS

This research was carried out from November 2019 to February 2020 at Public Company Perhutani Forest Management Unit Semarang at Grobogan, Central Java, Indonesia with limestone Margalite soil with chemical composition: N total, P available, K available 0.15% (low), 8.10 (medium), and 0.79 me 100 g^{-1} (high), respectively. A geographical position was between 110° 15'-111° 25' east longitude and between 7°1' - 7°30' south latitude with a height of 79 m above sea level (ASL), and the average rainfall is 201 mm $month^{-1}$.

The experimental design used in this research was a completely randomized block design (RCBD) with four replications. The first factor was a variety, which consisted of two levels, i.e., Dena I and Anjasmara. The second factor was shadingwhich consisted of four levels, i.e., 0; 10-20; 20-30; and 30-40%.

Soil tillage was done by plowing, then manure was a dose of 2 tons ha^{-1}. The plots were made in a size of 3.0 m x 3.0 m. The need for manure $plot^{-1}$ was 1.92 kg, Seeding was done by sowing the soybean seeds on the prepared planting media. Soybean seedlings were planted at a spacing of 40 cm x 15 cm. Phonska fertilizers were given according to the treatment, namely the first stage at 14 days and the second at 30 days after planting (DAP). Leaves fertilizer at a dosage of 75 kg ha^{-1} was given simultaneously at the age of 30 DAP in all plots. Irrigation cannot be done and only rely on rainwater. Plant maintenance carried out included transplanting at the age of 7 DAP and weed control at 14 DAP.

The parameters observed were the number of filled pods, the weight of dry pods, the weight of 100 seeds, and the weight of seeds ha^{-1}. The data of observations were analyzed using analysis of variance (ANOVA) at 5% significant levels. The treatment means were compared using Duncan's new multiple range test (DMRT) at 5% significant levels.

RESULTS AND DISCUSSION

Analysis of variance (Table 1) showed that there was an interaction between varieties and shade on the number of filled pods, dry pod weight, the weight of 100 seeds, and seed weight ha^{-1}.

Number of filled pods: Based on the analysis of variance (Table 1) in the number of filled pods there was an interaction between varieties and levels of shade. The highest number of filled pods was Anjasmara variety without shade that did not differ with 10-20% shade, Dena I variety without shade, or 10-20% shade. The minimum number of filled pods was Anjasmara variety with 30-40% shade which was not different from Dena 1 variety at 30-40% shade (Table 2).

Shade levels of 10-20% in varieties Dena 1 and Anjasmara have not caused a decrease in the number of filled pods, but starting at 20-30% shade levels, there is a decrease in the number of filled pods. The increasing the shade, the decrease in the number of filled pods will increase. The decrease in the number of filled pods of Dena I variety at 20-30 and 30-40% shade was 34.3 and 66.9%, respectively, while for Anjasmara variety was 61.8 and 74.8%.

The number of filled pods per plant in the shade-free environment in Dena 1 and Anjasmara varieties was 59.0 and 61.5 pods, respectively, while in the shaded environment the average was 35.58 pods and 30.17 pods (Table 2). The number of filled pods in plants in the shaded environment is less, which is reduced by about 40-50 percent and this situation occurs because the generative phase lacks light, which is the most sensitive phase to shade (Mathew *et al*. 2000) so that the pods fall easily (Jiang and Egli 1993). Sundari and Susanto (2015) reported that up to 75% shade intensity increased plant height and specific leaf area, but reduced leaf number and area, light absorption rate, photosynthesis rate, leaf chlorophyll index, the number of filled pods, and seed weight per soybean plant. With the presence of shade, stem diameter, total biomass, leaf area, the number of internodes on the main stem, and the number of branches all decreased (Wu *et al*. 2017).

The number of filled pods decreased with increasing shade stress (Table 2), which is similar to the study (Da-yong *et al*. 2012). The number of filled pods decreased by about 50% at 50% shade stress and even decreased by about 75% at 75% shade stress. A decrease in the number of filled pods can be caused by a lack of light for photosynthesis so that flowering and pod-forming plants easily fall off (Jiang and Egli 1993). It seems that Dena 1 variety has relatively little effect on pod number reduction compared to the Anjasmara variety.

One important effect of shade stress is a reduction in net photosynthesis (Liu *et al.* 2018). Shade on soybean plants results in taller stems, expanded leaves, reduced number of pods, reduced seed yields, and late ripening of pods (Susanto and Sundari 2011), other studies have shown that lack of light results in the reduced number of pods formed (Kurosaki and Yumoto 2003). Plant growth can be increased by increasing the efficiency of light-harvesting in shade conditions (Sundari and Susanto 2015) while Alridiwirsah *et al*. (2018), states that total chlorophyll, the highest was found on 50% shade intensity, the number of tillers, the highest was found on no shade intensity. Chlorophyll a and b play a role in the photosynthesis process of plants. Chlorophyll b functions as a photosynthetic antenna that collects light. The increase in chlorophyll b content in shaded conditions is related to an increase in chlorophyll protein so that it will increase the efficiency of the photosynthetic antenna function in Light-Harvesting Complex II (LHC II). The low radiation adaptation of the plant is also characterized by an enlarged antenna for photosystem II. Enlarging the antenna for photosystem II will increase the efficiency of light-harvesting (Hidema et al. 1992). Chlorophyll b functions as an antenna that collects light and then transfers it to the reaction center. The reaction center is composed of chlorophyll a. Light energy will be converted into chemical energy at the reaction center which can then be used for the reduction process in photosynthesis (Djukri and Purwoko, 2003).

Weight of dry pods: The weight of dry pods was influenced by the interaction between varieties and shade levels (Table 1). The highest dry pod weight was achieved by Dena I variety without shade, which was no different from the Anjasmara variety. The lowest dry pod weight for Anjasmara variety with 30-40% shade but not different from Dena I variety at the same shade level (Table 2). The weight reduction of dry pods in the shaded environment in Dena 1 and Anjasmara varieties was 55 and 59%, respectively.

The reduction in weight of dry pods in both Dena I and Anjasmara varieties was started at 10-20% shade. At 20-30% shade levels, both Dena 1 and Anjasmara varieties reduced the weight of dry pods by more than 50%.

The weight of dry pods in the shade-free environment for Dena 1 and Anjasmara varieties was 19.16 and 17.51 g, respectively, while in the shaded environment the average was 8.69 and 7.19 g (Table 2). The reduction in weight of dry pods in shaded plants was due to the photosynthesis process that did not run perfectly so that the net result of photosynthesis was not optimal. This is following the opinion of Khalid *et al*. (2019) that the presence of shade will reduce the activity of chlorophyll and photosynthesis. Light, temperature, humidity, etc. are important factors that affect the growth process of plants. Light is not only a major participant in plant photosynthesis, but also affects the relative content and quality of various macromolecules in plants through the formation and transport of photosynthetic products (Goto, Yamamoto, and Watanabe 1993), (Ohashi-Kaneko *et al*. 2006).

Zhang *et al*. (2016) added that in the soybean plant, short-term shading can reduce photosynthesis, leaf temperature, stomatal conductance, transpiration, and water use efficiency and increase intercellular CO_2 partial pressure, which leads to carbon gain and water loss. Soybean is an important legume crop that shows sensitivity to shade, if it gets shade the stems will elongate excessively, leading to falling apart and decreased yields (Lyu *et al*. 2021). Meanwhile, Kuswantoro and Maghfiro (2005) stated that providing shade at various growth stages had a significant effect on the number of flowers, number of pods, number of filled pods per plant, the weight of 100 seeds, and yield of dry soybean seeds.

In the relay strip corn-soybean intercropping system, the reduction in soybean photosynthesis was due to the adjustment of the leaf structure to capture light, and the effect of stomata characteristics on CO_2 absorption and translocation. Different shade-tolerant soybean varieties have significant differences in responding to different degrees of shade. Shade-tolerant varieties have advantages in the arrangement of leaf structure and stomata characteristics, which are more conducive to the progress of photosynthesis. Therefore, shade-resistant varieties show higher photosynthetic capacity and PSII activity, and biomass accumulation than shade sensitive varieties under shade conditions (Fan *et al*. 2020)

Weight of 100 seeds: The weight of 100 seeds was influenced by the interaction between the varieties and the level of shade (Table 1). The highest weight of 100 seeds was Dena 1 variety without shade and did not differ from 10-20% shade, Anjasmara variety without shade, 20-30, and 30-40% shade (Table 2). The lowest seed weight of the Anjasmara variety was 10-20% shade and did not differ from the Dena 1 variety with 20-30 and 30-40% shade.

The results of this study indicated that the weight of 100 seeds was less affected by the level of shade, but more dominantly influenced by the character of a variety. It is proven that the Anjasmara variety in shaded conditions (30-40%) soybean plants can still carry out the photosynthesis process and produce seeds with seed sizes that match their genetic characters, but in Dena 1 variety, 20-30% shade has experienced a weight loss of 100. seed. This is by the opinion of Tang *et al*. (2010) stated that shade treatment caused a decrease in seed yield but had no effect on seed size. The weight of 100 seeds represents the size of a seed. The weight of 100 seeds is influenced by genetic characteristics of each variety but also influenced by environmental factors including light intensity. The seed size of each genotype or variety gave different responses due to different light intensity treatments

Added by Ali *et al*. (2010) stated that soybean plants that grow in a shaded environment will decrease photosynthetic activity, so that the allocation of photosynthate to the reproductive organs is reduced, of course, this will result in a reduced number of pods, small seed size, and reduced seed yield. The light intensity of 60 or 40% shade can cause a decrease in soybean seed yields by up to 32% (Sundari and Susanto 2015). Kuswantoro and Maghfiro (2005) state that the length of shading during the growth of soybeans is approximately 84 days, from the vegetative phase to harvest, which will cause the allocation of photosynthate products not only for seed formation but also for the formation and development of other morphology. persist in gripping conditions.

Weight of seed: Based on the analysis of variance, there was an interaction between varieties and shade levels on seed weight ha^{-1} (Table 1). The highest seed weight ha^{-1} was in the Dena 1 variety without shade and was not different from the Anjasmara variety without shade. The lowest seed weight ha^{-1} of Anjasmara variety with 30-40% shade level, which was not different from 20-30% shade, and Dena 1 variety with 30-40% shade (Table 2).

Seed weight ha^{-1} in the shadeless environment for Dena 1 and Anjasmara varieties were 1692 and 1575 g, respectively, while in the shaded environment the average was 1196 and 963 g (Table 2). If it is broken down into different levels of shade, the decrease in yield ha^{-1} of Dena variety is 10-20, 20-30, and 30-40%, respectively 22, 14, and 50%, while the Anjasmara variety is 9, 49, and 59%.

The shade will reduce the seed weight ha^{-1} because the soybean crop lacks light. The function of light is for the photosynthesis process. As the shade increases, the rate of photosynthesis will decrease. Sundari and Susanto (2015) reported that up to 75% shade intensity increased plant height and specific leaf area, but reduced leaf number and area, light absorption rate, photosynthesis rate, leaf chlorophyll index, number of filled pods, and seed weight per soybean plant. Each plant genotype has a different tolerance to shade stress. Plants that are adaptive to low radiation experience an increase in leaf area ratio, stem leaf ratio, stem length, and decrease in leaf thickness (Haque *et al*. 2009). Susanto and Sundari (2011) reported that the growth and yield of soybean was influenced by the interaction of soybean genotypes with the environment

The light environment is one of the most critical environmental factors affecting plant growth and development (Gao et al. 2020). Shading not only causes changes in light intensity, but also causes changes in environmental factors such as light quality, air humidity, CO_2 concentration, and soil temperature (Shi et al. 2015). Reduction of absorbed light results in a reduction in photosynthetic activity so that the allocation of photosynthate to the reproductive organs is reduced. (Pekşen 2007) and as a result, seed yields decreased. Moula (2009) added to rice plants that the shaded and unshaded rice yields were 0.76 and 2.21 tons ha^{-1} respectively for the Kazol Shail variety and BRRI.-32 1.83 and 3.63 tons ha^{-1}.

Regarding variety, Chen *et al*. (2019), said that varieties had a significant effect on yield and each component factor, and light had a significant effect on spikelet filling, 1000 grain weight, and yield. Shading caused a significant reduction in the weight of 1000 grains and spikelet filling, which in turn led to a decrease in yield from 15.3 to 20.0%. The yield reduction using shade black nylon net is higher than under shading white cotton yarn.

In intercropping soybeans with maize, the yields of soybean with one row of corn and one row of soybeans, and two rows of soybeans planted in rows 40 cm wide were 54.69 and 16.83% lower than the single row of soybeans, respectively. These findings suggest that soybean plants can regulate the morphological characteristics and anatomical structure of leaves under different light environments (Yang *et al*. 2018)

CONCLUSION

The research results and the discussion above could be taken as follows. Shade decreased the number of filled pods, the weight of dry pods, the weight of 100 seeds, and the yield ha^{-1} of soybean varieties. The decrease in seed yield ha^{-1} of Devon 1 variety at 10-20, 20-30, and 30-40% shade was 22, 14, and 50%, respectively, while the Anjasmara variety was 9, 49, and 59%.

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Table 1. Analysis of variance all parameters

	Number of filled pods	Weight of dry pods	Weight of 100 seeds	Weight of seed ha^{-1}
Variety	0.76 ns	5.86 *	0.05 ns	9.00 **
Shading	23.43 **	89.11**	2.03 ns	31.33 **
Variety × shading	10.86 **	40.29 **	6.32 **	40.19 **
CV (%)	27.82	16.89	4.56	10.29

Table 2. Interactions of varieties and shading to the number of filled pods, the weight of dry pods, weight of 100 seeds, and weight of seeds ha^{-1}

Variety	Shading	Observation			
		Number of filled pods	Weight of dry pods (g)	Weight of 100 seeds (g)	Weight of seed ha^{-1} (g)
Dena 1	0	59.00 a	19.16 a	16.19 a	1692.00 a
	10-20	48.50 ab	11.40 b	16.06 a	1312.50 c
	20-30	38.75 bc	9.36 b	14.18 c	1446.50 bc
	30-40	19.50 d	5.30 cd	14.83 bc	830.75 d
Anjasmara	0	61.50 a	17.51 a	15.87 ab	1575.25 ab
	10-20	51.50 ab	11.78 b	14.04 c	1437.50 bc
	20-30	23.50 cd	6.55 c	15.60 ab	802.75 d
	30-40	15.50 d	3.23 d	16.08 a	651.00 d