Black Sea Journal of Agriculture
Open Access Journal
e-ISSN: 2618 - 6578

BSPublishers

Research Article
Volume 3 - Issue 1: 17-24 / January 2020

RESPONSES OF TWO SOYBEAN CULTIVARS ON GROWTH AND DEVELOPMENT IN TWO DIFFERENT LIGHT INTENSITIES

Achmad Yozar PERKASA[1,2]*, Ade SUMIAHADI[3], Hesti PUJIWATI[4], Muhammad Danang FAQIHHUDIN[5], Faradila Danasworo PUTRI[5]

[1]*Department of Field Crops, Faculty of Agriculture, Ankara University, Ankara 06120, Turkey*

[2]*Department of Agrotechnology, Gunadarma University, Depok, Indonesia*

[3]*Department of Agrotechnology, Faculty of Agriculture, Universitas Muhammadiyah Jakarta, Indonesia*

[4]*Department of Agrotechnology, Faculty of Agriculture, University of Bengkulu, Bengkulu, Indonesia*

[5]*Department of Agronomy and Horticulture, Bogor Agricultural University, Bogor, Indonesia*

Received: *May 08, 2019;* ***Accepted:*** *September 21, 2019;* ***Published:*** *January 01, 2020*

Abstract

Soybean is an important economic plant that prefers full sunlight and performs poor under shaded conditions that affect the reproductive phase of some soybean cultivars. The study aimed to find the interaction of soybean cultivars by comparing morphological, anatomical and physiological characters of two soybean cultivars on acidic soils under shaded and non-shaded conditions under West Java rainforest conditions to select against shade tolerance. The experiment was arranged in a split-plot design with two factors and used three replications. The main factor was the intensity of light (without and with 55% shading). The subfactor was soybean cultivars (Godek and Ceneng). The results showed positive effects of 55% shading on yield and yield components compared to those plants grown without shading. The 55% shaded plants had good growth with a large number of branches, leaf area index, leaf length, leaf width, and highest water content while non-shaded plants failed to grow properly with lower flowering, ratio of chlorophyll a/b, the number of root nodules and the sugar contents. The shaded plants also had the highest number of pods and pod weights after 8 weeks after sowing (WAS). It is concluded that high acidic Ultisol soil type can be managed to produce economic yields of soybean at pH of 4.8 which is below the recommended soil acidity under low shading conditions.

Keywords: Soybean, Cultivars, Development, Growth, Light intensity

***Corresponding author:** Department of Field Crops, Faculty of Agriculture, Ankara University, Ankara 06120, Turkey
E mail: perkasa@ankara.edu.tr (A.Y. PERKASA)

Achmad Yozar PERKASA	https://orcid.org/0000-0002-8327-1599
Ade SUMIAHADI	https://orcid.org/0000-0003-4738-5342
Hesti PUJIWATI	https://orcid.org/0000-0002-1329-2052
Muhammad Danang FAQIHHUDIN	https://orcid.org/0000-0003-4886-6893
Faradila Danasworo PUTRI	https://orcid.org/0000-0002-4176-8927

Cite as: Perkasa AY, Sumiahadi A, Pujiwati H, Faqihhudin MD, Putri FD. 2020. Responses of two soybean cultivars on growth and development in two different light intensities. BSJ Agri, 3(1): 17-24.

1. Introduction

Soybean (*Glycine max* L.) is an important agricultural crop that is grown worldwide. It is a major source of protein and oil for humans and animals. It also contributes to nitrogen fixation and improves soil fertility. The protein content of soybean is about 41% (Gerriets, 1993). Soybean seeds in Indonesia are the main raw material for the manufacture of tempeh, tofu, tauco, soy sauce, soy milk or soy flour (Winarso, 1985). Indonesian soybean production in 2017 reached ~40% of the national demand reaching 2.2 million tonnes (Ministry of Agriculture, 2017). Acidic soils have limited crop growth potential. Excess soluble or exchangeable Mn and Al cause toxicity in many crops in strongly acidic soils (Jackson et al., 1967).

Soybean generally grows well in soil that is neither too acidic nor too alkaline. Bekere et al. (2013) noted that nitrogen-fixing bacteria do not function effectively under low soil pH conditions of 4.2 and below while the recommended optimum pH is 6-6.5 for the proper growth of soybean. Uexkull and Bosshart (1982) have suggested low fertility of acid soils due to a combination of Al, Mn, Fe toxicity and P, Ca, Mg, K deficiency. The productivity of many acid soils is also reduced by physical factors related to soil texture that include low water holding capacity (Oxisols, Spodosols) and susceptibility to crusting, erosion especially compaction (Oxisols, Ultisols). Ultisols are found in geologically old landscape settings and characterized by a humus-rich surface horizon (the uppermost layer), by a layer of clay that has migrated below the surface horizon, and by a nutrient content low in available calcium, magnesium, potassium, and sodium. The well-developed, extensively leached soil horizons are enriched in kaolin group clay minerals and metal oxides and appear as red or bleached layers (Boardman, 1997). Occupying just over 8 percent of the nonpolar continental land area on Earth, they are found in humid temperate or tropical regions, including the southeastern United States and China, and in the humid tropics in South America and Africa (Boardman, 1997).

The soil used in this study had pH of 4.8 only. Such soils need good management to produce economically. This study was meant for proper management of such soils to get a high yield. Ultisols are reddish, clay-rich, acidic soils that support mixed forest vegetation prior to cultivation. They are naturally suitable for forestry, can be made agriculturally productive with the application of lime and fertilizers, and are stable materials for construction projects. Soybean plants require full sunlight to grow normally, but can still grow at certain shade levels; where, the intensity of sunlight is blocked by other competing higher plants that affect photosynthetic activity.

In the reproductive phase of some soybean cultivars, shade stress induces flowering and harvest earlier. Soybean cultivars require high light intensity at the photosynthesis and will certainly face problems if grown under low light. Generally, species of plants tolerant to low light intensity or shade tolerance will have a higher elasticity or plasticity in morphology and physiology to respond to changing environmental growth (Boardman, 1997; Chazdon et al., 1996).

Shade tolerant plants minimize their carbon losses by: (i) reducing respiration and reducing crop tissue reconstruction (Givnish, 1988), (ii) increasing the efficiency of photon capture by increasing chlorophyll levels (Lee et al., 1990), increasing leaf area and leaf thinning (Khumaida et al., 2003; Soepandie et al., 2005), and (iii) increasig nitrogen allocation for enzyme assimilation affecting chlorophyll formation (Murche and Horton, 1997).

There is no study showing the interaction of soybean grown under shaded and non-shaded conditions simultaneously on Ultisol soil types under rainforest conditions. Therefore, this study aimed to study the effects of natural shading of rainforest conditions (55% shading) with acidic Ultisol soil type on growth and yield of two Indonesian soybean cultivars.

2. Materials and Methods

The experiment was conducted from February to May 2013 at Leuwikopo Experimental Research Field of Bogor Agricultural University, Bogor, Indonesia that is located at an altitude of 250 m above sea level with geographical coordinates of 6° 24' 20" South, 106° 33' 39" East. The type of climate is a tropical rainforest climate (Af) according to Kopen Geiger system of climatic classification. The temperature averages 25.2°C. With about 4086 mm of precipitation falls annually, Leuwikopo has Ultisol type of soil with pH of 4.8 and wet silt clay loam texture containing 9.85% sand, 51.62% of volcanic dust, 38.53% of clay, 55.78% of moisture content, 1.32 gr cm^{-3} of dry bulk density and 2.051 gr cm^{-3} of wet bulk density. Laboratory analysis was conducted at the Laboratory of Post-harvest, Laboratory of UV-VIS and Spectrophotometry, Department of Agronomy and Horticulture, Bogor Agricultural University.

2.1. Experimental Design

This study used a split-plot design with 2 factors with three replications. The first factor consisted of different light intensities, i.e. full light (without shading) and low light intensity with a shading rate of 55% (light intensity in shade measured with lux meter). The second factor was soybean cultivars namely Godek and Ceneng. The experimental data were analyzed using univariate analysis of variance at α = 5% with SAS 9.1.3.

The materials used were Godek and Ceneng cultivars. The tools used are meter, knapsack sprayer, scales, oven, lux meter, hoe, stationery, and laboratory equipment for plant physiology analysis.

2.2. Field Trial

The Observations included: percentage of live plants, plant height, number of leaves, number of branches, length and width of leaf, leaf area index by gravimetric method at 6-8 WAS, number of flowers, chlorophyll content, leaf sugar content performed at the start of flowering, the weight of the harvest (wet pod, number of pods, and number of seeds per pod), wet and dry weight of plant.

2.3. Chlorophyll Content Analysis

Leaf sampling for chlorophyll, anthocyanin and carotenoid analysis was performed in the morning (07:00-08:00) as the leaves were no longer condensed. After the leaf samples were taken, they were brought to laboratory in a cool box (4°C) to prevent the biochemical degradation and shrinkage of wet weight before analysis.

The leaf samples (not less than 0.016 g and not more than 0.025 g) were cut and weighed. Before grinding them after adding 2 ml of acetris and then transferring them to 2 ml centrifuge tubes at 14,000 rpm for a few seconds about 1 ml of supernatant was inserted in a reaction tube and then added 3 ml of acetris to make the total solution of 4 ml (dilution factor = 4). These were covered with marbles to reduce evaporation. Absorbance values were seen in spectrophotometers with wavelengths 663 (chlorophyll b), 647 (chlorophyll a), 537 (anthocyanin), and 470 (carotenoids). To obtain the value of chlorophyll, anthocyanin, and carotenoids, the absorbance value was determined using the formula of Arnon (1949).

$$\text{Anthocyanin total} = (0.08173 * A537) - (0.00697 * A647) - (0.002228 * A663)$$

$$\text{Chlorophyll a} = (0.01373 * A663) - (0.000897 * A537) - (0.003046 * A647)$$

$$\text{Chlorophyll b} = (0.02405 * A647) - (0.004305 * A537) - (0.005507 * A663)$$

$$\text{Carotenoid} = A470 - (17.1 * (Chla + Chlb) - 9{,}479 * \text{Anthocyanin})) / 119.26$$

2.4. Analysis of Sugar Content

Extraction of sample ingredients was done according to Rose et al. (1991): plant leaves were dried in an oven, ethanol 80%, perchloric acid ($HClO_4$) with a concentration of 9.2 N (diluted to 793 ml in 70% $HClO_4$ in 1 liter of water) and 4.6 N (diluted to 397 ml in 70% $HClO_4$ in 1 liter water).

<u>Procedure;</u>

a. The plant tissues were crushed until smooth followed by insertion 100 g of plant tissue each into centrifuge tubes.
b. It was followed by adding 10 ml of 80% ethanol and were covered up with in tube with marbles.
c. The tubes were placed in warm water 80-85°C for 30 minutes.
d. These were centrifuged and poured into a glass of 50 ml in 3 repeats.
e. These were evaporated for alcohol in warm water 80-85°C.
f. It was followed by adding 25 ml of distilled water.

Then the analysis of sugar content was performed in the following way. Material: antron, stock solution glucose to make 100 mg l^{-1} solution.

<u>Procedure;</u>

a. Glucose solution 0, 1 and 2 ml were fed into a pyrex test tube by adding 5ml to each tube.
b. Dilution of 5 ml of the extract was transferred into a 100 ml measuring flask.
c. 5 ml of the dilution was incorporated into a new pyrex test tube.
d. Pyrex test tube and standardized tubes were cooled in ice water.
e. Antron 10 ml was added to each tube.
f. These were gently stirred
g. The tubes were put in boiling water for 7.5 minutes.
h. The tubes were inserted into the ice.
i. When cold, their absorbance was measured at 630 nm.

3. Result

The shade-sensitive comparison cultivars as originally planned (Godek) could not grow at all. This was presumed that the seed quality of this soybean cultivar was not good that caused the seeds could not do the germination. For this reason, the results of this study show only the data obtained from Ceneng cultivar. In order to study the possible different responses of soybean plants to shaded conditions, one new treatment was applied. The new treatment was 55% shading applied 8 WAS when the vegetative phase of the plants was about to end. This additional treatment was aimed to study the late shading treatment on the generative development of soybean plants.

3.1. Viability

Based on the observations, the germination of Ceneng cultivar without shading was lower than that of Ceneng cultivar with 55% shading (Table 1). In the treatment with 55% shading, soybean had 100% germination. On the other hand, non-shaded soybeans had 86% germination rate in the first week and increased to 94.5% in the second week.

Table 1. Viability of soybean Ceneng cultivar at 1 and 2 weeks after sowing

Treatments	1 WAS	2 WAS
55% shading	100	100
Without shading	86	94.5

3.2. Plant Height

The results showed that soybean in shaded conditions had higher plant height compared to the non-shaded plant (control) from the beginning to the end of observation (Table 2).

Table 2. Effect of shade on soybean height Ceneng cultivar on 1-9 weeks after sowing (WAS)

Treatments	Plant Height (cm)								
	1 WAS	2 WAS	3 WAS	4 WAS	5 WAS	6 WAS	7 WAS	8 WAS	9 WAS
55% shading	12.40	17.10	26.05	36.15	55.25	68.95	76.55	84.60	89.35
Without shading	5.69	11.72	16.12	24.38	34.69	47.82	64.86	76.21	86.97

3.3. The Number of Leaves

Based on the data obtained from the experiment, more leaves were noted on soybean with shade compared to leaves on non-shaded soybean plants. However, after one week after sowing, an equivalent number of leaves was noted on the shaded and non-shaded soybean plants. It was noticed that the number of leaves also increased in both treatments in older age. The number of leaves was directly proportional to the height of the plants (Table 3).

Table 3. Effect of shading on number of soybean leaves at 1-9 weeks after sowing (WAS)

Treatments	Number of Leaves								
	1 WAS	2 WAS	3 WAS	4 WAS	5 WAS	6 WAS	7 WAS	8 WAS	9 WAS
55% shading	1	1.9	4.6	5.7	15.1	23.4	30.1	34.4	38.6
Without shading	1.0	2.3	4.1	6.2	7.7	10.7	16.0	23.7	27.2

3.4. The Number of Branches

The soybean plants under shade conditions had a larger number of branches compared to that on non-shaded soybean plants [control, (Table 4)].

Table 4. Effect of shadings on number of branches of soybeans at 4-9 WAS

Treatments	Number of Branches					
	4 WAS	5 WAS	6 WAS	7 WAS	8 WAS	9 WAS
55% shading	0.60	3.20	3.90	6.10	6.30	6.70
Without shading	0.00	0.70	1.70	3.93	4.03	4.63

3.5. Leaf Area Index (LAI), Leaf Length and Leaf Width

It can be seen that the leaf area of shaded soybean was wider than the non-shaded soybean. In observations of 6, 7 and 8 weeks after sowing, the larger leaf area index was also influenced by the length and width of soybean leaf at 8 weeks after sowing observations (Table 5). The number of leaves also affects the leaf area index value. In the leaf number parameter, shaded soybean plants had more leaves than the non-shaded soybean cultivars (Table 2). The shading treatment had a significant effect ($p \leq 0.05$) on the leaf length for all harvest times. Leaf area in shaded treatment was longer than non-shaded treatment.

Table 5. Effect of shadings on leaf area index, length and width of leaves on soybeans

Treatments	Leaf area index			Length and width of leaf at 8 WAS	
	6 WAS	7 WAS	8 WAS	Leaf length	Leaf width
55% shading	2.95	3.80	4.34	12.16	8.30
Without shading	0.74	1.94	3.78	11.00	8.36

3.6. Time Appears Flower and The Number of Flowers

Soybean plants with shading flowered faster than soybean grown without shading and the number of flowers per plant was less than soybean without shading (Table 6).

Table 6. Effect of shadings on flowering time and number flowers of soybeans

Treatments	Flowering time (Days After Sowing)	Number of flowers per plant
55% shading	70.00	12.00
Shading 8 WAS	63.00	3.30
Without shading	66.67	29.00

3.7. Chlorophyll content

Based on table 7, the ratio of chlorophyll a/b in the shaded treatment was lower than of the other two treatments. The chlorophyll a/b ratio in shaded soybean was 2.10726 while in soybean with shading 8 WAS was 2.12493 and soybean without shading was 2.14577 (Table 7).

3.8. Nodules of Root, Wet Weight, Dry Weight and Water Content of Shoot and Root

Based on the data obtained, the shaded soybeans had a higher wet and dry weight of shoot, the water content of shoot, wet weight root, and water content of root than in the plants grown without shading and with shading 8 WAS (Table 8). However, in the variable of root nodule weight, non-shaded soybean plants had the highest weight of root nodules compared to the other two treatments.

Table 7. The content of chlorophyll in shaded soybeans, sheltered at 8 weeks after sowing and non-shaded

Treatments	Chlorophyll a	Chlorophyll b	Ratio of Chlorophyll a/b
55% shading	0.00659	0.00313	2.10726
Shading 8 WAS	0.00733	0.00345	2.12493
Without shading	0.00559	0.00261	2.14577

Table 8. Effect of shadings on wet weight, dry weight, water content of shoot and root and weight of root nodules

Treatments	Wet weight of shoot (g)	Dry weight of shoot (g)	Water content of shoot (%)	Wet weight of root (g)	Dry weight of root (g)	Water content of root (%)	Weight of root nodules (g)
55% shading	243.30	51.10	79	20.20	4.80	77	63.20
Shading 8 WAS	189.73	39.93	75	16.70	2.84	78	33.70
Without shading	179.00	48.02	71	18.87	5.15	71	118.33

3.9. Number and Weight of Pods

More pods were induced on the shaded soybean plants, and soybean plants with shading 8 WAS have the highest number of total pods along with pods weight (Table 9). In this study, it was also showed that soybean Ceneng cultivar without shading could only produce very low productive pods and very high unproductive (empty) pods compared to that with shading treatments.

Table 9. Effect of shadings on number and weight of pods of soybeans

Treatments	Number of productive pods	Number of empty pods	Number of total pods	Weight of pods (g)
55% shading	9.60	7.60	17.20	4.21
Shading 8 WAS	37.75	19.25	58.50	17.48
Without shading	0.45	43.93	44.23	8.38

3.10. Sugar Content

Sugar contents in non-shaded plants are higher than those in both shaded plants (Table 10). Soybeans with shading at 8 WAS had a 7% decrease in sugar content while shaded soybeans from the beginning had a 10% decrease in sugar content.

Table 10. Soybean sugar content Ceneng cultivar in three shade treatments

Treatments	Sugar content (mg l^{-1})
55% shading	160.23
Shading 8 WAS	164.65
Without shading	178.21

4. Discussion

Soybean cultivation in Indonesia is primarily done in West Sumatera with Köpen Geiger tropical rain forest Af type of climate that has Latosols and Red Yellow Podzolics types of soils with deep ground water and good soil structure. Acidic soils are one of the most important limitations to agricultural production worldwide (Kochian et al., 2004). Ultisols are reddish, clay-rich, acidic soils that support mixed forest vegetation. They can be made agriculturally productive with the application of lime and fertilizers. Healthy seeds can germinate easily under optimum conditions.

The plant height variable of this study was consistent with the Anggraeni (2010), who showed that 50% shading gives a significant effect on the increase of plant height in the various cultivars. Plants with shade grew taller compared to non-shaded plants (controls) in agreement with Pantilu et al. (2012). Sitompul and Guritno (1995) emphasize that plant height was a parameter of light-sensitive environmental influences.

It is assumed that the shade affected movements of auxin from its place of synthesis downward and increased the plant length with the induction of new increased number of shoots and regulated morphogenesis within the plant body (Franklin, 1991; Jumin, 1992 in Litouw, 2005) with increased rate of photosynthesis due to increasing radiation capture.

Mariani (2009) showed similar results, 50% of shaded soybean plants had more branches than those not covered by both tolerant soybean and sensitive soybean crops. It was assumed that this was because the shaded plants had to maximize the process of catching light by forming more branches that in turn induced multiple leaves to maximize light capture.

Increased leaf area index in the higher shade and maximum fertilization dose was due to an increase in total leaf area with an increasing number of leaves. The increase in leaf area index was one of the mechanisms to increase the efficiency of light capture in agreement with Taiz and Zeiger (2002).

This result was in line with the reports of Baharsjah (1980), Silaen (2004) and Evita (2011) which showed that the higher shade level affects positively in quick induction of flowers with higher interception of light during flowering phase and indicated faster, induction of more flowers, and seeds per bean under shaded condition.

Plants require enough carbohydrates to enter the reproductive phase. Carbohydrates are produced from the process of photosynthesis. Jumin (1992) emphasized that the intensity of sunlight was highly correlated to the rate of photosynthesis. According to Larcher (1975), the increased intensity of sunlight could lead to an increase in photosynthesis and increased assimilation of the plant. Unprotected plants have a high rate of photosynthesis that could cause the plant to meet the need for faster carbohydrates to enter the generative phase so the plants that are not shaded will flower faster.

Chlorophyll content was in line with the study from Muhuria (2007) of chlorophyll a/b ratio decreased by 50% light intensity treatment which means that there was an increase in chlorophyll b content. Increased chlorophyll b was associated with increased light harvesting of chlorophyll a/b photosystem II (LHCIIb) protein. Similarly, Khumaida et al. (2003) reported that the shade-tolerant soybean genotype has a greater capture capacity than the sensitive genotype because it has a higher ability to convert chlorophyll a to chlorophyll b. According to Hale and Orchutt (1987), shaded plants usually have a lower chlorophyll a/b ratio than plants exposed to light. This was due to an increase in the number of chloroplasts and chlorophyll concentrations in shaded plant chloroplasts, followed by a decrease in other pigments that interfere with the light absorption process.

Chlorophyll response to low light intensity was important as chlorophyll a and chlorophyll b are complex components of chloroplast peripheral antennas determined by the accepted light conditions as a form or mechanism of plant adaptation. Hidema et al. (1992) emphasized that increasing the antenna size for PSII can improve the efficiency of light-harvesting. When the plants get low light intensity, the chloroplast could move to the outer surface to maximize light absorption for photosynthesis.

The shaded soybeans had a higher dry weight of shoot than that of soybeans with shading at 8 WAS. Hale and Orcut (1987) emphasized that the adaptation to low light was done by reducing the allocation of photosynthates to roots. Silaen (2004) showed that higher canopy dry weight and soybean roots under shade were more important. This was because of soybean plants do not need 100% light intensity that interferes with physiological processes in plants (Fitter and Hay, 1991).

Widiastuti (1998) emphasized total pods in non-shaded soybean plants were higher than shaded soybean crops. This was probably because the shaded plants receive only low light which results in the low rate of photosynthesis so that the number of pods was also low. The results of this study are also supported by reports from da Mota (1978), Anwari (1992) and Justika et al. (1993). The low number of pods on sheltered plants was also suspected to result from the absence of flowers and pods. According to Jiang and Egli (1993) shading could result in interest absorption of 36% and 73% pod absorption. Meanwhile, deficiency and toxicity in Ultisols led pod setting and pod filling in Ultisols disrupted and caused a decreasing number of filled pods. This results show that the total pods is lower than the result of Kuswantoro and Zen (2013) that reported up to 114 pods per plant in full rainy season. Therefore, water also presumably the main factor regulating pod setting apart from the soil pH.

Sugar content was similar to that of Liu et al. (2011) where shade decreased total dissolved sugar by 14 to 43% in soybean crop in 2007-2008. Wilcox (2001) emphasized that the total dissolved sugar has a close relationship with the process of photosynthesis and has an important role in the metabolism of carbohydrates. This statement was supported by Wang et al. (2007) who reported the photosynthate content formed from soluble carbohydrates with dissolved sugar as one of the main components. Saratha et al. (2001) emphasized and observed that the total level of dissolved sugar was a measure of the ability of the leaves as the source and the ability of plants to convert the assimilate into seeds.

One limiting factor of photosynthesis was the availability of light in plants. The plant compensation point used in the shade was lower than that of unobstructed crop compensation. This causes the rate of assimilation of carbon in shaded plants was lower than plants non-shaded, resulting in decreased levels of sugar in the leaves.

The decrease in sugar levels will reduce the amount of assimilating produced and will directly reduce the intake of photosynthates to plant sinks such as pods. By decreasing the intake of photosynthesis, the development of the pod will slow down so that the plant cannot achieve optimal production at the right time.

5. Conclusion

Differences in characteristic of soybean of Ceneng cultivar in shaded, shaded at 8 WAS and non-shaded conditions induced the differences of plant height, number of leaves, number of branches, leaf area index, leaf length, leaf width, flower time, number of flowers, a/b chlorophyll ratio, water content, sugar content, and yield components. The shaded plants showed higher plant height, number of leaves, number of branches, leaf area index, leaf length, leaf width and water content of plant (shoot and root). Soybean plants that grew with shading also had the maximum number of flowers, the ratio of chlorophyll a/b, the number of root nodules and the sugar content. In addition, non-shaded soybean plants had a shorter flowering time, while soybean plants with shading at 8 WAS had the highest number of pods and pods weight.

Significance of Statements

This study discovered the responses of soybean Ceneng cultivar on growth and development in two different light intensities on Ultisol soil type under rainforest conditions with a pH of 4.8 that can be beneficial for Indonesian farmers to reap an economic yield under different light conditions. This study will help the researchers to uncover the critical areas of soybean growth and development under acidic soils in tropical rain forest climate that many researchers were not able to explore earlier.

Conflict of interest

The authors declare that there is no conflict of interest

Acknowledgment

The authors would like to thanks the research advisors Prof. Dr. Khalid Mahmood Khawar Bhatti and all colleagues for the invaluable assistance, support, and advice during this research study.

References

Anggraeni BW. 2010. Morpho-anatomical studies and soybean growth (*Glycine max* (L.) Merr.) under low-intensity stress conditions. Thesis. Bogor Agricultural University.

Anwari M. 1992. Adaptation of soybean genotype to shade. In: Machmud M, Kardin K, Gunarto L, editor. Commodity Research and Case Studies 1991. Bogor: Crops Research Institute. pp. 373-380.

Arnon DI. 1949. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in Beta vulgaris. Plant Physiol, 24: 1-15.

Baharsjah JS. 1980. Effect of shade at various stages of development and population of plants on growth, yield and component of soybean yield (*Glycine max* (L.) Merrill). PhD Thesis. Bogor: Bogor Agricultural University.

Bekere W, Kebede T, Dawud J. 2013. Growth and nodulation response of soybean [*Glycine max* (L.) Merrill] to lime, *Bradyrhizobium japonicum* and nitrogen fertilizer in acid soil. Inter J Soil Sci, 8(1): 25-31.

Boardman NK. 1997. Comparative photosynthesis of sun and shape plant. Annu Rev Plant Physiol, 28: 355-377.

Chazdon RL, Pearcy RW, Lee DW, Fetcher N. 1996. Photosynthetic responses of tropical forest plants to contrasting light environmental. In: Mulkey SS, Chazdon RL, Smith AP, editor. Tropical Forest Plant Ecophysiology. New York: Chapman and Hall. pp. 5-55.

da Mota FS. 1978. Soya Been and Weather. Swiss: World Meteorology Organization.

Evita. 2011. Growth and yield of some soybean varieties (*Glycine max* (L.) Merrill) on artificial shade. J Penlt Jambi University Sci Series, 13(2): 19-28.

Fitter AH, Hay RKM. 1991. Physiology of Plant Environment. Andani S, Purbayanti ED, translator. Yogyakarta: UGM Pr. pp. 53-79.

Franklin G. 1991. Crop Culture Physiology. Jakarta: UI Pr. p. 428.

Gerriets M. 1993. To build a better soybean. Agr Res, 41(10): 5-11.

Givnish TJ. 1988. Adaptation to sun and shade a whole-plant perspective. Aust J Plant Physiol, 15: 63-92.

Hale MG, Orchutt DM. 1987. The physiology of plants under Stress. New York: John Willey and Sons.

Hidema J, Makino A, Kurita Y, Mae T, Ohjima K. 1992. Changes in the level of chloropyhyll a/b protein of PSII in rice leaves agent under different irradiances from full expansion through senescence. Plant Cell Physiol, 33: 1209-1214.

Jackson TL, Knox EG, Halvorson AR, Barker AS. 1967. Crop response to lime in the F. Western United States, p. 261-269. In: Pearson W and Adams, editors. Soil Acidity and Liming. Madison: Am Soc Agron, 274 pp.

Jiang H, Egli DB. 1993. Shade induce change in flower and pod number and flower and fruit abscition in soybean. Agron J, 85: 221-225.

Jumin HB. 1992. Plant ecology. Jakarta: Rajawali Pr.

Justika SB, Suardi D, Las I. 1993. Climate relationship with soybean growth. In: Somaatmadja S, Ismunadji M, Sumarno, Sham M, Manurung SO, Yuswadi, editors. Soy. Bogor: Center for Food Crops Research and Development, pp. 87-102.

Khumaida N, Soepandie D, Takano T. 2003. Adaptability of soybean to shade stress: Expression of photosynthetic genes in soybean genotypes. Proceeding of the 1st seminar toward harmonization between development and enviroment conservation in biological production. Tokyo: Tokyo University.

Kochian LV, Hoekenga OA, Pineros MA. 2004. How do crop plants tolerate acid soil? Mechanism of aluminum tolerance and phosphorous efficiency. Annual Rev Plant Biol, 55: 459-493.

Kuswantoro H, Zen S. 2013. Performance of acid-tolerant soybean promising lines in two planting seasons. Int J Biol, 5: 49-56.

Larcher W. 1975. Physiological Plant Ecology. New York: Springer-Verlag.

Lee DW, Bone RA, Tarsis SL, Storch D. 1990. Correlates of leaf optical properties in tropical forest sun and exireme-shade paints. Amer J Bot, 77:370-380.

Litouw LI. 2005. Efficiency of Solar Radiation Usage On Pakchoi Plant (*Brassica chinensis* L. Var.Chinensis). Thesis. Manado: Sam Ratulangi University.

Liu B, Li Y, Liu X, Wang C, Jin J, Herbert SJ. 2011. Lower total soluble sugars in vegetative parts of soybean plants are responsible for reduced pod number under shading conditions. Aus J Crop Sci, 5(13): 1852-1857.

Mariani SM. 2009. Effect of shade intensity and combination of N and P fertilization on growth, simplicia production and andrographolidean content at bitumen. Thesis. Bogor: Bogor Agricultural University.

Ministry of Agriculture of The Republic of Indonesia. 2017. http:/deptan.go.id/bpsdm/ddppketindan/index.php/news/165-week-soy-national. (Access date: June 21, 2017).

Muhuria L. 2007. Physiology Mechanism and Inheritance of Soy Tolerance (*Glycine max* (L.) Merrill) to Low Light Intensity. Bogor: Bogor Agricultural University.

Murche EH, Horton P. 1997. Acclimation of photosynthesis to irradiance and spectral quality in British plant spesies: chlorophyll content, photosynthetic capacity and habitat preference. Plant Cell Environ, 20: 438-448.

Pantilu LI, Mantiri FR, Ai NS, Pandiangan D. 2012. The morphological and anatomical responses of soybean sprouts (*Glycine max* (L.) Merrill) to different light intensities. J Bioslogos 2(2): 79-87.

Rose R, Rose CL, Omi SK, Forry KR, Durall DM, Bigg WL. 1991. Starch determination by perchloric acid vs enzymes: evaluating the accuracy and precision of six colorimetric methods. J Agric Food Chem, 39: 2–11.

Saratha K, Hume DJ, Godfrey C. 2001. Genetic improvement in short season soybeans: matter accumulation, partitioning, and leaf area duration. Crop Sci, 41: 391-398.

Silaen S. 2004. The effect of shading on the growth and production of some soybean varieties (*Glycine max* L. Merril) in polybags. MS Thesis. Medan: Universitas Sumatera Utara.

Sitompul SM, Guritno B. 1995. Analysis of plant growth. Yogyakarta: UGM Pr.

Soepandie D, Trikoesoemaningtyas, Khumaida N. 2005. Physiology, genetic and molecular adaptation of soybean to low light intensity development of soybean superior varieties as intercropping plants. Year II Report of the HPTP Graduate-Research Grant. Bogor: Bogor Agricultural University.

Taiz L, Zeiger E. 2002. Plant Physiology. Massachussetts: Sinauer Associates Inc. Pub.

Uexkull HR, Bosshart RP. 1982. Management of acid upland soils in Asia. In: Craswell ET and Pushparajah E, editor. Management of Acid Soils in the Humid Tropics of Asia. Australian Centre for International Agricultural Research. pp. 2-19.

Wang XH, Xu KZ, Li DY, Zhang ZA, Wu ZH, Chen ZY, Zhang XR. 2007. Variation of soluble sugar content and specific leaf weight during the genetic improvement of soybean cultivars. Soybean Sci, 26: 879-884.

Widiastuti SH. 1998. Analysis of growth and yield of soybean to shade with combination of chemical fertilizer and grean gaint NPK on coconut cultivation. Thesis. Bogor: Bogor Agricultural University.

Wilcox JR. 2001. Sixty years of improvement in publicly developed elite soybean lines. Crop Sci, 41: 1711-1716.

Winarso FG. 1985. Processing of soybeans into oil and industrial ingredients. In: Somaatmaja S, Ismunadji M, Sumarno, Sham M, Manurung SO, Yuswandi, editors. Soy. Bogor: Center for Food Crops Research and Development, pp. 483-509.