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Morpho-Physiological responses of brown-seeded soybean genotypes under low light intensity

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Abstract. The objective of the study was to know the responses of morphological and physiological traits of brown-seeded soybeanunder low light intensity. The study was conducted using the Experimental Method and the Split Plot Design was used in the experiment. The main plot was light intensity (L) and the subplot was genotypes (G). The main plot consists of L0 (fully light intensity) and L1(low light intensity, under black shading net of 65% light intensity). The brown-seeded soybean consists of 13 genotypes (KH 7B, KH 7C, KH 7D, KH 9, KH 14, KH 50B, KH 35, KH 8B, KH 31A, KH 35E, Ceneng, Burangrang, and KH1). The 13 genotypes were planted in pots in three replicates. Results of the study showed that: (1)The morpho-physiological responses of brown-seeded soybean varied under the low light intensity: the plant height, the leaf area, and the chlorophyll A and B contents increased, but the number of productive branches, the number of leaves, the specific leaf weight, the number of seeds per plant, the number of filled pods, the number of empty pods, and the seed weight per plant decreased. (2) Under the low light intensity, KH9 indicated the highest plant height, number of productive branches, number of leaves, and chlorophyll b content but the lowest seed size (100 seed weight), KH35E produced a high number of seeds per plant and filled pods, KH1 indicated the highest of the 100 seed weight, KH35 tends to produce the highest seed weight per plant, chlorophyll A content, and stable of the seed weight per plant.

Keywords: morpho-physiology, response, brown-seeded soybean, genotype, low light intensity

1. Introduction

There are two species of soybean cultivated in Indonesia, namely *Glycine max* (yellow-seededand green-seeded soybean) and *Glycine soja* (black-seeded soybean).*Glycine max* originated from Asia subtropics such as RRC and Southern Japan, while*Glycine soja*originated from Asia tropics of South West Asia [1].Black-seeded soybean (*G. soja*) should perform better growth and yield in Indonesia compared to yellow-seeded soybean. Kisman *et al.* [2,3,4] reported thatfor many purposes, some soybean breeders do cross breedings between yellow-seeded soybeans and black-seeded soybeans and produce brown-seeded soybean lines.Under the Research Center for Genetic Resource Management of legumes, tubers, and horticulture of the Faculty of Agriculture, UniversitasMataram more than thirty advanced lines of brown-seeded soybeans have been developedgenerated from yellow and black-seeded soybean crosses.

Different colors of soybean seeds due to various content of anthocyanin pigment accumulation in the soybean seed coat. More anthocyanin content in the seed coat, more black color of the seed coat. The accumulation of anthocyanin pigment in the seed coat of soybean is controlled by some genes, such as gene I and R pleiotropic genes. Wirnas *et al.*[5] reported that black-seeded soybean has high anthocyanin content andno anthocyanin in yellow-seeded soybean.

In the Agricultural Revitalization Program, soybean is the third major food crop after rice and maize that the government prioritizes to develop and increase its production [6]. The Ministry of Agriculture plans a soybean development target to increase production by 7% per year to reach 2.2 million tons by 2020 with a productivity of 2.3 tons/ha. Efforts to increase soybean production to achieve the target stipulated are carried out through land expansion, the use of superior varieties and appropriate cultivation techniques [7].

The increase in national soybean production through land optimization and expansion of planting areas has considerable potential, among others through land use under plantation crops, industrial plant forests through agroforestry programs, or intermingled with other seasonal food crops. The main obstacle to soybean development under the stand or the intrusionsystem is the low intensity of light due to the shade factor. According to Asadi and Arsyad [8]; Asadi *et al.* [9], the intensity of light decreased to 75% under the plant and 33% under the overlap with corn or sorghum. Soybean plants require optimum solar radiation (approx. 0.3-0.8 cal/cm^2/min equivalent to 431-1152 cal/cm^2/day) with spectrum or wavelengths ranging from 400-700 nm (called photosynthetically active radiation, PAR) to obtain high photocinotic net yields [10, 11]. In addition to playing a dominant role in the process of photosynthesis, the light also serves as a controller, trigger, and modulator of morphogenesis response especially in the early stages of plant growth [12]. Anderson [13] also explained that plants that grow in the murmuring environment find it difficult to express their genetic potential in its entirety to grow, develop, and produce to the maximum. It was reported that soybean yields decreased by an average of 30-60% in the shading conditions. Handayani [14] also reported that due to a 50% shade deftness, yields per hectare of soybean decreased by 10-40%. Therefore, breeding efforts are needed to acquire genotypes or new superior varieties of soybeans capable of adapting to shade stress environments.

The objective of the study was to know the responses of morphological and physiological traits of brown-seeded soybean genotypes under low light intensity.

2. Materials and methods

Thirteen genotypes of soybean were used as the genetic materials. This study was conducted using an experimental method. The experimental design used was a split-plot design, where the main plot was light intensity (L): L0 =fully light intensity (normal condition)and L1 = low light intensity (65% light interception), andthe subplot was13 genotypes (G): G1 = KH 7B, G2 = KH 7C, G3 = KH 7D, G4 = KH 9, G5 = KH 14, G6 = KH 50B, G7 = KH 35, G8 = KH 8B, G9 = KH 31A, G10 = KH 35E, G11 = Ceneng, G12 = Burangrang, and G13 = KH 1. The subplot was done in three replicates. The low light intensity was conditioned under a black shading net house (65% light interception). The shading net house was constructed with a frame of 8 m in length, 6 m width, and 2 m in height.

The entisol soil was used as planting media taken from rice fields in Narmada sub-district. The dried-sifted soilwas then mixed with manure with a ratio of 2:1 and7 kg of the soil was thenfilled intothe 20 cm diameter pot. As the experimental units, the pots wereset at a distance of 25 x 25 cm either under low light or fully light intensity conditions.

Before planting, the seeds of the 13 genotypes were treated with a Marshall 25 ST insecticide with the dosage of 15 g/kg of seeds. Three soybean seeds were planted in each of the pots. One week after planting, two healthy plants were left per pot. After 14 days of the seedlings grown under the full light intensity then the low light intensity treated plants were moved into the shading net house and some pots were left under normal conditionsuntil the harvesting date.

Plant maintenance was carried out through fertilization, pest and disease control, and watering. Urea, SP36, and KCl fertilizers were given in three times: 3, 15, and 30 days after planting (DAP) with a dose of 1/3 of the total dose of 50 kg of urea, 100 kg of SP36, and 50 kg of KCl per hectare on each time. Protecting the plants from pest insects and diseases was done by periodically spraying Dursban and Dethane M-45 insecticides base on the recommended doses. Watering the plants was also carried out every three days periodically.

The morphological characters observed consist of plant height (cm), number of productive branches (branches), number of trifoliate leaves (leaves), leaf area of trifoliate leaves (cm^2), specific leaf weight (SLF) (g/cm^2),flowering date (DAP), harvesting date (DAP),number of filled pods, the weight of 100 seed (g), and the weight of the seed per plant (g). The physiological characters consist ofthe content of chlorophyll A and chlorophyll B and the ratio of chlorophyll A/B. The analysis of chlorophyll content was carried out following the Richardson [15] procedure.

The data were analyzed using analysis of variance 5 % level then were further followed by Honestly Significant Difference (HSD) with 5% level of difference. The analysis was conducted using Minitab 13.

3. Results and discussion

3.1 Morphological Characters

The analysis of variance of 5% level of the morphological characters invegetative phase (plant height, number of productive branches, number of leaves, and specific leaf weight) of brown-seeded soybean genotypes(Table 1) showed that there weresignificantly different morphological responses of genotypes under different light intensity. Except for the specific leaf weight, the genotypes of brown-seeded soybean varied significantly on all morphological characters of vegetative phase (plant height, number of productive branches, number of leaves, leafarea, specific leaf weight, number of the trichome, and trichome length) under different light intensity. Table 1 also showed that low light intensity conditions affected the morphological characters of the generative phase such as the number of seeds per plant, the number of filled pods, the number of empty pods, and the weight of the seeds per plant. Genotype factors had significant effects on all generative morphological characters observed (flowering date, harvesting date, number of seeds per plant, number of filled pods, number of empty pods, and weight of 100 seeds) except the weight of the seeds per plant.

As indicated in Table 2, the average plant height under low light intensity conditions (112.28 cm) increased more than twice from normal conditions (53.67 cm). This was similar as reported by Pantilu *et al*. [16] that the plant height of soybean higher under shading than in normal conditions. This was presumably due to the normal work of the hormone of auxin to accelerate the growth of the stem and the addition of the length of the internodes under low light intensity conditions. Under low light intensity, the highest plant of brown-seeded soybean was KH 9 (190.33 cm) and the lowest was Ceneng (70 cm). Under normal conditions, the highest plant was indicated by KH7C (72.33 cm) and the lowest was KH35E (29.00 cm). KH 9 showed 128.83 cm higher, the highest increased in plant height under low light intensity conditions compared to full light intensity condition, and the least increased of plant height was Ceneng (23.00 cm). Ceneng is one of the shade-tolerant soybean genotypes[17,18].

Table 1. Analysis of variance of the morphologicalresponses of brown-seeded soybean under low light intensity.

SV	Morphological Characters													
	PH	NPB	NL	LA	SLW	NT	TL	FD	HD	NSP	NFPd	NEPd	HSW	SWP
L	s**	s**	s**	ns	s*	ns	ns	ns	ns	s**	s**	s*	ns	s*
G	s**	s**	s**	s**	s**	s**	s**	s**	s**	s**	s**	s**	s**	ns
G*L	s**	s**	s**	s**	ns	s**	s**	s*	ns	s*	ns	s**	ns	ns

Description. ns = non significant; s* Significantly difference at 5% level;s** Significantly difference at 1% level; SV = source of variance; PH = plant height; NPB = number of productive branches; NL = number of leaves; LA = leaf area; SLW = specific leaf weight; NT = number of trichomes; TL = trichome length; FD = flowering date; HD = harvesting date; NSPd = number of seeds per pod; NSP = number of seeds per plant; NFPd = number of filled pods; NEPd = number of empty pods; HSW = 100 seed weight; SWP = seeds weight per plant.

The number of productive branches of all soybean genotypes showed a decrease of about 1.46 branches under low light intensity. This was similar as reported by Sundari and Wahyuningsih [19] that soybean grown under shade stress show a small number of branches, even no branch. The reduced intensity of light received by plants will result in impaired growth and differentiation of cells, tissues, and plant organs, which is indicated by the reduced number of branches and the number of filled pods. Under low light intensity conditions, KH9 shows the highest number of productive branches (10.33 branches) and the fewest wasCeneng (2.33 branches). Compared to normal conditions,Ceneng showed the highest decrement of the number of productive branches (about 71%).

The highest number of leaves under low light intensity was indicatedby KH35 (28.67 leaves) and the lowest was Burangrang (10.67 leaves). Compared to fully light intensity, KH9 showed the most decreased in the number of leaves under low light intensity (20 leaves). The highest leaf area under low light intensity was indicated byKH7D (176.15 cm^2) and the lowest was showed by Ceneng (104.57 cm^2). The highest increased in the leaf area under low light intensitywas indicated byKH35E (58.28cm^2). According to Pantilu *et al.* [16], the low light intensity causes plants have larger and thinner of leaves, larger of stomata size, thinner of epidermis cell layers, more leaves, and more space between cells.

The highest trichome length under low light intensity was indicated by Burangrang (4.82 mm) and the shortest was KH7C (2.35 mm). Compared to normal conditions, the most decreased length of the trichomes was indicated by the Burangrang (3.10 mm) while the KH14 showed an increase in the trichome length (0.68 mm). This was presumably a form of avoidance mechanism of soybean against shade stress. According toLevitt [20] in Pantilu *et al.*[16], mechanism of avoidance relates to the changes of leaf anatomy and morphology to maximize the efficiency of light capture and photosynthesis, such as an increase of leaf area as well as decrease of leaf thickness, number of cuticles, wax, and trichomes.

The response of morphological characters in the generative phaseas indicated in Table 3 showed that the genotypes of brown-seeded soybean varied in the flowering date, the number of seeds per plant, and the number of empty pods per plant under different light intensity. KH35E was the highest flowering date (52.7 DAP) under the normal condition as well as under low light intensity (47.7 DAP). While KH1 was the lowest flowering date in both conditions (36.7 DAP under normal condition and 34.0 DAP under Low light intensity). In terms of different magnitudes, KH35E indicated the highest decreased of the flowering date under low light intensity, while KH7C showed the highest increase of flowering date under low light intensity.

Table 2. Morphological responses in the vegetative phase of brown-seeded soybean genotypes under low light intensity.

Descrip-	Morphological characters in the vegetative phase						
tion	PH	NPB	NL	LA	SLW	NT	TL
L0	53.666B	6,590A	26,410A	133,229	0,250A	10,291	4,443
L1	112.282A	5.129B	18.692B	147.432	0.237B	7.496	3.636
G1	88.667cd	5.5bc	24.666cde	155.526ab	0.230b	5.723cd	2.802e
G2	94.167bc	6.166abc	24.000cdef	159.730a	0.225b	5.722cd	2.748e
G3	92.167cd	5.833abc	25.833bcd	158.337a	0.230b	4.943d	2.562e
G4	128.833a	9.166a	34.666a	122.168b	0.232b	7.612bcd	3.710cde
G5	74.833cdefg	6.333abc	25.333cde	136.982ab	0.252ab	9.000bcd	4.148bcde
G6	85.833cde	6.000abc	28.833abc	134.362ab	0.255ab	8.833bcd	4.137bcde
G7	121.667ab	7.833ab	34.500ab	130.540ab	0.249ab	8.443bcd	3.902cde
G8	74.833cdefg	5.166bc	15.333fg	143.833ab	0.240ab	5.777cd	3.113de
G9	82.833cdef	6.000abc	19.000defg	126.260ab	0.237ab	10.665abc	4.767abcd
G10	66.167defg	6.166abc	17.333defg	142.467ab	0.230b	11.778ab	5.135abc
G11	58.500efg	4.833bc	14.333g	131.730ab	0.247ab	6.502bcd	3.243de
G12	56.167fg	3.500c	12.500g	144.823ab	0.262ab	15.890a	6.363a
G13	54.000g	3.667c	16.833efg	137.533ab	0.284a	14.723a	5.888ab
G1L0	67.667a	7.667	30.000bcd	168.117 a	0.250	6.223d	2.913d
G2L0	72.333a	7.000	28.333bcd	145.927abc	0.243	6.890cd	3.150d
G3L0	64.000ab	7.000	31.667abc	140.523abc	0.233	5.110d	2.563d
G4L0	67.333a	8.000	44.667a	93.453d	0.223	8.000cd	3.753cd
G5L0	50.667abc	6.667	31.667abc	124.743abcd	0.243	8.223cd	3.807cd
G6L0	67.333a	6.333	36.000ab	130.400abcd	0.250	8.333cd	3.896cd
G7L0	62.000abc	8.333	40.333ab	118.213bcd	0.247	9.886bc	4.340bcd
G8L0	58.333abc	5.000	14.000e	138.137abcd	0.253	7.000cd	3.513cd
G9L0	46.333abc	7.667	20.000cde	125.297abcd	0.240	11.110bcd	4.817abcd
G10L0	29.000c	6.333	17.333de	113.327cd	0.240	15.667abc	6.343abc
G11L0	47.000abc	7.333	17.333de	158.887ab	0.256	7.557cd	3.533cd
G12L0	32.333bc	4.333	14.333e	128.057abcd	0.277	20.890a	7.910a
G13L0	33.333bc	4.000	17.667de	146.893abc	0.297	18.890ab	7.217ab
G1L1	109.667bc	3.333b	19.333 abc	142.936ab	0.210	5.223	2.69abc
G2L1	116.000bc	5.333ab	19.667 abc	173.533a	0.207	4.553	2.347c
G3L1	120.333b	4.667b	20.000 abc	176.153a	0.227	4.777	2.56bc
G4L1	190.333a	10.333a	24.667 ab	150.883ab	0.240	7.223	3.667abc
G5L1	99.000bc	6.000ab	19.000abc	149.223ab	0.260	9.777	4.490abc
G6L1	104.333bc	5.667ab	21.667 abc	138.323ab	0.260	9.333	4.377abc
G7L1	181.333a	7.333ab	28.667a	142.867ab	0.250	7.000	3.463abc
G8L1	91.333bc	5.333ab	16.667 abc	149.533ab	0.227	4.553	2.713abc
G9L1	119.333b	4.333b	18.000 abc	127.223ab	0.233	10.220	4.717abc
G10L1	103.333bc	6.000ab	17.333 abc	171.607ab	0.220	7.890	3.927abc
G11L1	70.000c	2.333b	11.333c	104.573b	0.237	5.447	2.953abc
G12L1	80.000bc	2.667b	10.667c	161.593ab	0.247	10.890	4.817a
G13L1	74.667bc	3.333b	16.000bc	128.173ab	0.270	10.557	4.560abc

Notes. The figures of factors (L, G, G*L) followed by the same characters in the same column indicate not significantly difference at 5% level; PH = plant height; NPB = number of productive branches; NL = number of leaves; LA = leaf area; SLW = specific leaf weight; NT = number of trichomes; TL = trichome length

Mostly, the number of seeds per plant decreased under low light intensity and KH9 indicated the highest decreased (108.3 seeds) or about 46% from the number of seeds per plant under normal conditions. While only KH8B showed an increased number of seeds per plant (40.0 seeds around 31.6%) under low light intensity.

Table 3. Morphological responses in the generative phase of brown-seeded soybean genotypes under low light intensity.

Description	FD	HD	NSP	NFPd	NEPd	HSW	SWP
L0	41.692	89.051	193.513A	89.897A	1.820A	8.934	15.054A
L1	41.103	91.103	129.257B	62.436B	0.358B	9.710	11.102B
G1	40.000cde	85.167d	176.667abc	76.333bcd	0.167b	7.548bc	12.857
G2	41.667cd	85.667d	195.333abc	84.167bc	1.167ab	7.412bc	14.315
G3	40.500cde	84.833d	203.333abc	95.500abc	0.667b	7.427bc	15.600
G4	41.833cd	91.000bcd	181.833abc	99.333abc	2.833ab	5.957c	11.180
G5	40.167cde	85.167d	164.333abc	69.333bcde	0.333b	7.628bc	12.294
G6	39.667cde	84.833d	196.500abc	79.667bc	0.333b	7.198bc	13.837
G7	42.333bc	92.833abc	213.833ab	103.00ab	1.167ab	7.301bc	14.623
G8	45.167b	92.833abc	146.667bcd	70.500bcde	1.333ab	6.995bc	10.129
G9	45.000b	92.833abc	143.833cd	67.500cde	0.667b	8.516b	11.780
G10	50.167a	98.667a	222.000a	124.333a	4.833a	6.742bc	14.708
G11	37.500ef	97.500ab	87.167de	39.167e	0.000b	15.763a	13.749
G12	38.833de	90.667bcd	73.333e	38.667e	0.500b	15.783a	11.194
G13	35.333f	89.000cd	93.167de	42.667de	0.166b	16.920a	13.759
G1L0	40.000cde	85.666cd	229.000abc	96.666abcd	0.333b	7.400b	16.206
G2L0	40.667cde	85.667cd	246.667a	97.333abcd	0.667b	7.437b	18.220
G3L0	41.333cd	85.667cd	244.333a	110.333abc	0.333b	7.253b	18.360
G4L0	41.667cd	84.000cd	236.000abc	127.667ab	5.667ab	5.667b	13.893
G5L0	40.667cde	85.000d	205.667abcd	81.667bcd	0.000	7.757b	15.470
G6L0	39.667def	84.000d	243.667ab	93.667abcd	0.333b	6.737b	16.293
G7L0	42.667bc	90.667bc	258.667a	119.000abc	2.333ab	6.067b	14.543
G8L0	45.333b	91.000abc	126.667bcde	66.667cd	2.000ab	7.150b	8.937
G9L0	45.333b	91.000abc	178.333abcde	86.667bcd	1.333b	8.283b	14.120
G10L0	52.667a	96.000ab	234.000abc	146.000a	9.667a	6.587b	15.233
G11L0	37.000fg	96.333a	108.667de	46.333d	0.000	15.167a	16.727
G12L0	38.333efg	90.667bc	83.333e	43.000d	0.667b	14.403a	11.800
G13L0	36.667g	89.000cd	120.667cde	53.667d	0.333b	16.240a	15.907
G1L1	40.000bc	84.667c	124.333bc	56.000 abcd	0.000	7.697b	9.507
G2L1	42.667abc	85.667bc	144.000abc	71.000 abcd	1.667	7.387b	10.410
G3L1	39.667bcd	84.000c	162.333ab	80.667abc	1.000	7.600b	12.840
G4L1	42.000abc	95.000abc	127.667abc	71.000 abcd	0.000	6.247b	8.467
G5L1	39.667bcd	85.333bc	123.000bc	57.000abcd	0.667	7.500b	9.117
G6L1	39.667bcd	85.667bc	149.333ab	65.667abcd	0.333	7.660b	11.380
G7L1	42.000abc	95.000abc	169.000ab	87.000ab	0.000	8.537b	14.703
G8L1	45.000ab	94.667abc	166.667ab	74.333abcd	0.667	6.840b	11.320
G9L1	44.667ab	94.667abc	109.333bc	48.333bcd	0.000	8.750b	9.440
G10L1	47.667a	101.333a	210.000a	102.667a	0.000	6.897b	14.183
G11L1	38.000cd	98.667ab	65.667c	32.000d	0.000	16.360a	10.770
G12L1	39.333bcd	90.667abc	63.333c	34.333cd	0.333	17.163a	10.587
G13L1	34.000d	89.000abc	65.667c	31.667d	0.000	17.600a	11.610

Notes. The figures of factors (L, G, G*L) followed by the same characters in the same column indicate not significantly different at 5% level; FD = flowering date; HD = harvesting date; NSPd = number of seeds per pod; NSP = number of seeds per plant; NFPd = number of filled pods; NEPd = number of empty pods; HSW = 100 seed weight; SWP = seeds weight per plant

The low light intensity condition showed a significant influence on the number of seeds per plant. The number of seeds per plant of all genotypes under low light intensity conditions was significantly decreased (64.26 seeds). Under Low light intensity, the number of seeds per plant is 129.26 seeds, the highest was indicated by KH35E (210 seeds), while the lowest was indicated by Burangrang

(63.33 seeds). The most declined number of seeds per plant was indicated by KH9 (108.33 seeds), while KH8B showed an increase in the number of seeds per plant under low light intensity (40 seeds).

The number of empty pods per plant also indicated different magnitude and direction of changing under different light intensity. KH35E indicated the highest number of empty pods (9.7 pods) under normal conditions but no empty pods under low light intensity. Ceneng showed no empty pods in both conditions but Ceneng showed 0.7 empty pods under low light intensity increased from no empty pods under normal conditions. The highest decreased of the empty pods (9.7 seeds) was indicated by KH35E.

The number of filled pods under low light intensity(62.43 pods) was 30% lower than the full light intensity conditions (89.90 pods). Under low light intensity, KH35E showed the highest number of filled pods (102.67 pods) and the lowest was indicated by KH1 (31.67 pods). KH35E showed the highest decreased in the number of filled pods under low light intensity (43.3 pods), while KH8B showed an increase in the number of fill pods under low light intensity (7.67 pods).

The highest of 100 seed weight was indicated by KH1 (16.92 g) no significant difference with the Ceneng and Burangrang, and the lowest was KH9 (5.96 g). Most of the 100 seed weight of brown-seeded soybean genotypes increased under low light intensity.The weight of seeds per plant of all genotypesunder the low light intensitywas 11.10 g, lower 27% than under normal conditions (15.05 g). The seed weight per plant of KH7C decreased 50% under low light intensity. The reduction of light intensity has an impact on the disruption of the photosynthesis process. According to Hay and Porter [21], the rate of photosynthesis of soybean increases linearly with the increase of light intensity.

3.2. Physiological Characters

Based on the analysis of variance 5% level, the physiological responses of brown-seeded soybean genotypes were significantly varied under different light intensity only on the number of opened and closed stomata, while the content of chlorophyll A and B was affected by genotype factors but not affected by low light intensity (Table 4).

Table 4. The analysis of variance of the physiological responses of brown-seeded soybean under low light intensity.

SV	Physiological Responses				
	NOS	NCS	Chl A	Chl B	Chl A/B
L	s**	ns	ns	s*	s*
G	s**	s**	s**	s**	ns
G*L	s**	s**	ns	ns	ns

Description. ns = non significant; s* Significantly difference at 5% level;s** Significantly difference at 1% level; SV = source of variance; NOS = number of opened stomatas; NCS = number of closed stomatas; Chl A = chlorophyll A; Chl B = chlorophyll B; Chl A/B = ratio of chlorophyll A/B

Based on further analyses of the different physiological responses (Table 5) showed the average number of opened stomata under low light intensity was 33.76 stomata, 19% lower than under normal conditions (41.50 stomata). Ceneng had the highest of opened stomata under normal conditions (51.56 stomata) and the lowest one under low light intensity (24.89 stomata). KH9 showed the highest number of opened stomata under low light intensity and KH35 was the lowest one under normal conditions. Ceneng showed the most reduction in the number of open stomata due to low light intensity (reduced 52% opened stomata), meanwhile the KH35increased 43% of the number of open stomata under low light intensity.

Table 5. Physiological responses of brown-seeded soybean genotypes under low light intensity.

Description	NOS	NCS	Chl A	Chl B	Chl A/B
L0	41.503A	6.616	2.085B	1.045B	1.988
L1	33.761B	4.573	2.779A	1.733A	1.664
G1	43.943a	7.333ab	1.333d	0.680e	1.959
G2	42.167ab	4.557ab	1.312d	0.750de	1.766
G3	39.778abc	6.612ab	1.665cd	0.938cde	1.796
G4	38.777abc	5.112ab	2.858a	1.892a	1.612
G5	40.333abc	4.502ab	2.862a	1.638abc	1.794
G6	31.388c	6.612ab	2.980a	1.915a	1.638
G7	31.280c	8.445a	2.540ab	1.388abcde	2.002
G8	40.722abc	6.555ab	3.117a	1.613abc	1.947
G9	34.612abc	5.610ab	2.965a	1.763ab	1.784
G10	39.665abc	4.333ab	3.107a	1.662ab	1.945
G11	38.222abc	4.333ab	2.512ab	1.417abcd	1.794
G12	32.998bc	5.613ab	2.413abc	1.330abcde	1.860
G13	35.335abc	3.110b	1.957bcd	1.070bcde	1.847
G1L0	50.887a	10.000abc	1.203c	0.626c	1.922
G2L0	48.110a	5.443bcd	1.240c	0.653c	1.899
G3L0	46.557a	6.223bcd	1.313c	0.700bc	1.876
G4L0	38.443ab	7.000bcd	2.577ab	1.340ab	1.923
G5L0	42.777ab	8.113bcd	2.353abc	1.196abc	1.967
G6L0	26.777b	10.113ab	2.707ab	1.397a	1.938
G7L0	25.780b	14.557a	2.223abc	1.047abc	2.123
G8L0	49.220a	5.553 bcd	3.033a	1.447a	2.096
G9L0	41.557ab	4.110bcd	2.546ab	1.207abc	2.109
G10L0	42.777ab	4.443bcd	2.517ab	1.150abc	2.189
G11L0	51.557a	3.890cd	2.140abc	1.130abc	1.894
G12L0	39.443ab	3.780d	1.703bc	0.857abc	1.987
G13L0	35.667ab	2.7706d	1.553bc	0.807abc	1.924
G1L1	37.000ab	4.667	1.463d	0.733c	1.996
G2L1	36.223abc	3.670	1.383d	0.847bc	1.633
G3L1	33.000abcd	7.000	2.017cd	1.176abc	1.715
G4L1	39.110a	3.223	3.140abc	2.413a	1.301
G5L1	37.890a	0.890	3.370ab	2.080ab	1.620
G6L1	36.000abc	3.110	3.253ab	2.433a	1.337
G7L1	36.780ab	2.333	3.253abc	1.730abc	1.880
G8L1	32.223abcd	7.567	3.200abc	1.780abc	1.798
G9L1	27.667bcd	7.110	3.383ab	2.320a	1.458
G10L1	36.553abc	4.223	3.697a	2.173ab	1.701
G11L1	24.887d	4.777	2.883abc	1.703abc	1.693
G12L1	26.553cd	7.467	3.123abc	1.803abc	1.732
G13L1	35.003abc	3.443	2.360bcd	1.333abc	1.770

Notes. The figures of factors (L, G, G*L) followed by the same characters in the same column indicate not significantly different at 5% level; NOS = number of opened stomata; NCS = number of closed stomata; Chl A = chlorophyll A; Chl B = chlorophyll B; Chl A/B = ratio of chlorophyll A/B

The chlorophyll A content was mostly affected by genotype, not by light intensity. The highest chlorophyll A was indicated by KH35E and KH8B and the lowest was indicated by KH7B and KH7C. The chlorophyll B content was affected by genotype and also light intensity but not due to the interaction of both factors (Table 5). The chlorophyll B content increased about 66% under low light intensity, and the ratio of chlorophyll A/B slightly decreased. KH9 and KH50B showed the highest chlorophyll B content (around 1,90 mg/g) and the lowest was indicated by KH7B (0.68 mg/g). The results of this study are in line with those were reported by Jufri [22]; Muhuria [23] thatunder low light intensity conditions, tolerant genotypes have a higher chlorophyll B content and a lower chlorophyll A/B ratio than sensitive genotypes. Kisman *et al*. [19] also reported that the chlorophyll B content of soybean increased under low light intensity and decreased the ratio of chlorophyll A/B. Increased chlorophyll B is associated with increased light harvesting of chlorophyll A/B protein photosystem II (LHCIIb). Since the most chlorophyll B is a light-harvesting component of PSII, the change in chlorophyll A/B ratio reflects changes in the number of light harvester complexes (LHCs) in PSII and PSI. Same as reported by Yustiningsih [24], that shade plants have a high ratio PS II / PSI and high ratio chlorophyll A/B to increase the light-harvesting complex and make photosynthesis efficiently.

4. Conclusion

Based on the results and discussions above, it can be concluded that:

a. The morpho-physiological responses of brown-seeded soybean varied under low light intensity: plant height, leaf area, and chlorophyll A and B contents increased, but the number of productive branches, the number of leaves, specific leaf weight, the number of seeds per plant, the number of filled pods, the number of empty pods, and seed weight per plant decreased.

b. Under low light intensity, KH9 indicated the highest plant height, number of productive branches, number of leaves, and chlorophyll B content but the lowest seed size (100 seed weight), KH35E produced a high number of seeds per plant and filled pods, KH1 indicated the highest of seed size (100 seed weight), KH35 tends to produce the highest seed weight per plant, chlorophyll A content, and stable seed weight per plant.

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