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Morphological and Physiological Characteristics of Shading Tolerant and Sensitive Mungbean Genotypes

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Study of morphological and physiological characteristics of the tolerant and sensitive mungbean genotypes to shading was carried out in the Station Research of the Indonesian Legume and Tuber Crops Research Institute (ILETRI) from September to December 2004. Nine tolerant genotypes (MMC 87 D-KP-2, MLG 369, MLG 310, MLG 424, MLG 336, MLG 428, MLG 237, MLG 429, and VC2768B) and three sensitive genotypes to shading (Nuri, MLG 460, and MLG 330) were tested in two shading levels, that were without shading and shading of 52%. The randomized complete block design with three replications analysis. The results showed that leaf characters of shading tolerant and sensitive genotypes were different. The shading tolerant mungbean genotypes had good response to light stress so that the growth and development of the leaves were better than that of sensitive genotypes. The shading tolerant mungbean genotypes had bigger and thicker leaves than that of sensitive genotypes. The shading treatments caused reducing rate of PAR absorption, transpiration, photosynthesis, and CO_2 stomata conductance. The reduction of all parameters in tolerant genotype was smaller than that of sensitive genotype. The specific leaf area at four weeks after planting could be used as shading tolerant indicator of mungbeans.

Key words: mungbean, characteristics, morphology, physiology, leaves, tolerant, sensitive, shading

INTRODUCTION

Shading is a factor affecting the plant productivity at plantations of agriculture as well as forestry crop. Shading was an important phenomenon to be known and if it was possibly to be controlled. Shading will cause decreasing of quantity and quality of the sunlight intercept to the crop, and it will affect the productivity of photosynthesis.

Respones of most crop to change in light intensity varies depend on the species (Thompson *et al*. 1992). Light intensity requirement of each plant species was different depended on the age, environment condition, and length of day. The physiological behavior of young plants of *A. rosaeodora* to different light intensities suggests that its photosynthetic apparatus was more efficient when they were grown on medium light intensity (500 a 1000 $\mu mol.m^{-2}.s^{-1}$). However, their photosynthetic activity were suppessed when they were grown in low or height light intensity (de Carvalhu Gonsales *et al*. 2005).

Effect of low irradiance on leaf of C_3 plants lead to phenotypic changes in their photosynthetic apparatus. The shade tolerant species had wider leaves, and played a role to the absorbtion of photosynthetically active radiation (PAR) under low irradiance (St-Jacques *et al*. 1991; Poorter *et al*. 1995). The aim of this research was to determine leaf morphological and physiological characteristics of mungbean shading tolerant and sensitive genotypes.

MATERIALS AND METHODS

The research was conducted in the Kendalpayak research station of the Indonesian Legume and Tuber Crops Research Institute (ILETRI) from September to December 2004. The place was located at 450 m above sea level, which had Entisol soil and with C3 climate type according to Oldeman. Nine shading tolerant genotypes of mungbean (MMC 87 D-KP-2, MLG 369, MLG 310, MLG 424, MLG 336, MLG 428, MLG 237, MLG 429, and VC2768B) and three sensitive genotypes (Nuri, MLG 460 and MLG 330) were tested on two different shading levels, i.e. without shading and 52% shading. The experiment was set up using randomized complete block design with three replications.

The treatment of 52% shading was set up using two layers of black screen at the high of 1.8 m from soil surface. The light intensity was measured using Lux meter.

Each genotype was planted five seeds per hole, with planting distance of 0.40 x 0.15 m. Fertilization was applied at the time of planting with 50 kg ha^1 Urea, 50 kg ha^1 KCl, and 100 kg ha^1 SP36. The thinning was conducted at ten days after planting by leaving two crops per hole. The thinning and weeding were done at four weeks after planting (WAP). The pest and disease control, were conducted regularly every three days.

Observation of leaf number, leaf area, specific leaf area (SLA), rate of PAR absorbtion, photosynthesis, transpiration

activities, the stomatal CO_2 conductance and chlorophyll content was conducted regularly every two weeks from four weeks up to harvest. The leaf area was measured by the gravimetric methods (Sitompul & Guritno 1991). The specific leaf area (SLA) was measured by the SLA = ((LAi/LDWi). The chlorophyll content was observed using spectrophotometric method. The rate of PAR absorption, photosynthesis, transpiration and stomatal CO_2 conductance were observed using LCi Portable Photosynthesis System (3015). The data were statistically analyzed using Duncan's test in the 5% á level and Contrast of Ortogonal test.

RESULTS

Effect of Shading on Leaf Number and Morphology. Leaf number at six and eight WAP was difference (Table 1). Generally, leaf number at without shading treatment more than that of shading treatment. The greatest leaf number at six WAP was achieved by MLG 429 genotype and the fewest was found on MLG 460 genotype. The greatest leaf number at eight WAP was achieved by Nuri genotype and the fewest was found on MLG 424, MLG 460, and MLG 330 genotypes. Interaction of genotype and shading also had a significant effect to leaf area (Figure 1). Except MLG 424 genotype, all tested genotypes showed negative response to shading.

In four and eight WAP, interaction between genotype and shading showed the significant effect on the specific leaf area (SLA) (Table 1). SLA was increased sharply at the initial growth, then it was constant at initial generative phase and it was decline in the further phases (Table 1).

Results of the contrast test (Table 2) showed that leaf area and morphology of shading tolerant genotypes were different from shading sensitive genotypes. Leaf area of shading tolerant genotype was bigger than that of sensitive genotype at four and six WAP. Leaf number of shading tolerant and sensitive genotypes did not show the difference, however leaf number reducing of tolerant genotype was relatively less than that of sensitive genotype, especially at six and eight WAP. SLA values of shading tolerant and sensitive genotypes did not show significant difference, except at four WAP. At four WAP, SLA value of shading tolerant genotypes smaller than that of sensitive genotypes. It mean that leaves of shading tolerant genotypes were thicker than that of sensitive genotypes (Table 2).

Plant Physiology. Photosynthetically active radiation (PAR) absorption rate of each genotype showed significant difference (Figure 2). The result showed that shading treatment caused reduction of PAR absorption rate at four and six WAP. The highest reduction of PAR absorption rate was reached by MLG 429 genotype and the lowest was found on MLG 424 and MLG 428 genotypes at four and six WAP respectively. At eight WAP, the highest reduction of PAR absorption rate was reached by MLG 310 genotype and the lowest by VC 2768B genotype (Figure 2).

Genotype and shading interaction had significant effect to transpiration rate (Figure 3). The shading treatment could reduce transpiration rate. At four WAP, the highest reduction of transpiration rate was achieved by MLG 429 genotype and the lowest was found on MLG 369 genotype (Figure 3a). The highest reducing of transpiration rate in six WAP was reached

Table 1. Leaf number per plant and specific leaf area (cm^2/g) of twelve mungbean genotypes at two shading levels

Shade (%)	Genotypes	Leaf number at:			Specific leaf area (cm^2/g) at:		
		4 WAP	6 WAP	8 WAP	4 WAP	6 WAP	8 WAP
0	MMC 87 D-KP-2	12	22efgh	21e	276.8efg	214.8	140.6 k
0	MLG 369	13	26de	26c	267.1efg	220.2	189.8gh
0	MLG 310	13	25ef	26c	285.5ef	216.8	192.2g
0	MLG 424	13	22efg	20ef	347.9d	218.8	175.2ghi
0	MLG 336	14	24ef	29b	240.4hi	216.8	160.4ijk
0	VC 2768B	14	26de	24d	286.8e	190.0	148.6jk
0	MLG 428	14	18ghij	27c	284.0ef	199.1	165.7ij
0	MLG 237	13	29cd	26c	236.8i	194.4	162.6ijk
0	MLG 429	15	41a	26c	257.9ghi	232.2	235.2def
0	Nuri*	16	36b	32a	288.1e	226.2	179.4ghi
0	MLG 460*	15	22efg	18fg	281.2efg	219.7	193.1g
0	MLG 330*	13	31c	26c	261.4fgh	211.5	168.3hij
52	MMC 87 D-KP-2	11	17ij	16hi	338.3d	252.3	193.0g
52	MLG 369	12	16ij	15i	376.1bc	310.9	268.1abc
52	MLG 310	11	16ij	15i	371.1c	304.1	246.3cde
52	MLG 424	13	19ghij	14i	342.2d	314.4	255.6bcd
52	MLG 336	13	17ij	15i	383.2bc	287.8	250.2cd
52	VC 2768B	12	17hij	17gh	399.6ab	294.9	226.2ef
52	MLG 428	12	19ghij	18g	379.7bc	285.3	218.7f
52	MLG 237	15	22efgh	20e	344.9d	300.6	277.6ab
52	MLG 429	14	23efg	21e	396.7ab	344.9	289.2a
52	Nuri*	13	21fghi	21e	417.9a	322.8	276.0ab
52	MLG 460*	14	15j	14i	389.6bc	253.1	197.1g
52	MLG 330*	12	19ghij	14i	382.6bc	323.2	244.6cde
Variance coefficient (%)		11.03	11.03	10.42	4.07	12.85	6.21

in the same column, the number was followed the different letter showed was significantly according to the DMRT test 5%; WAP: the week after planted; *: the genotype was sensitive to the shading.

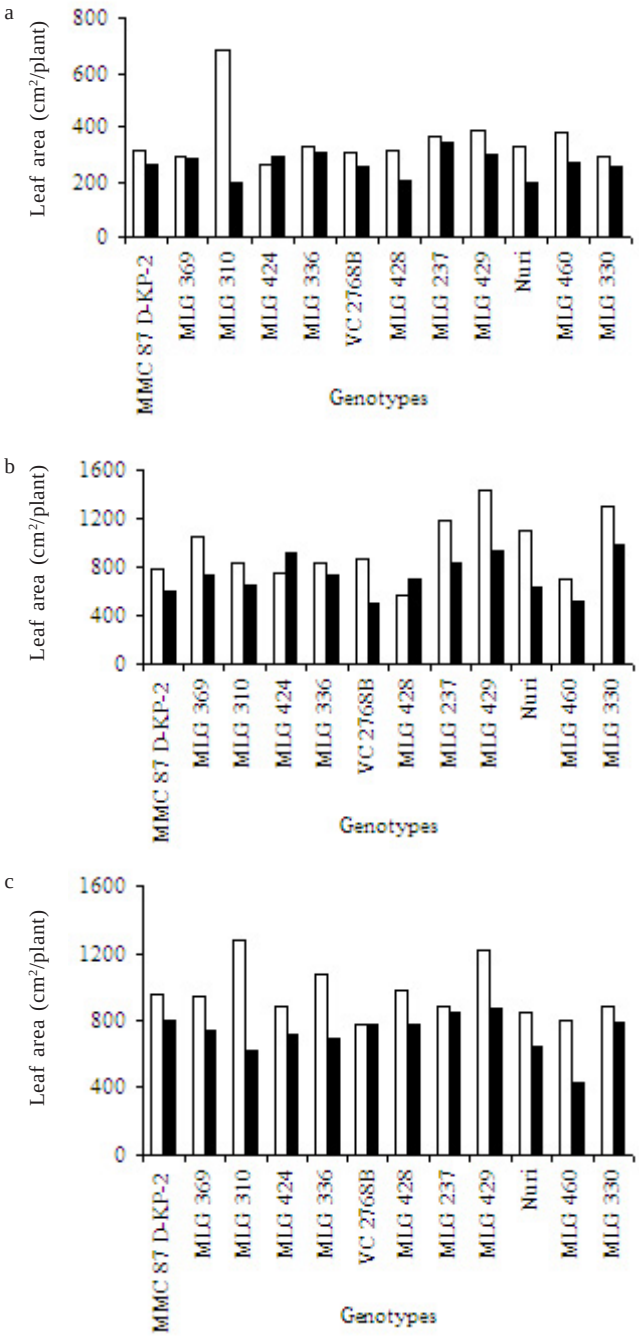

Figure 1. The leaf area (cm²/plant) at: (a) 4, (b) 6, and (c) 8 WAP of twelve mungbean genotypes in without shading and 52% shading level. □: without shading, ■: 52% shading.

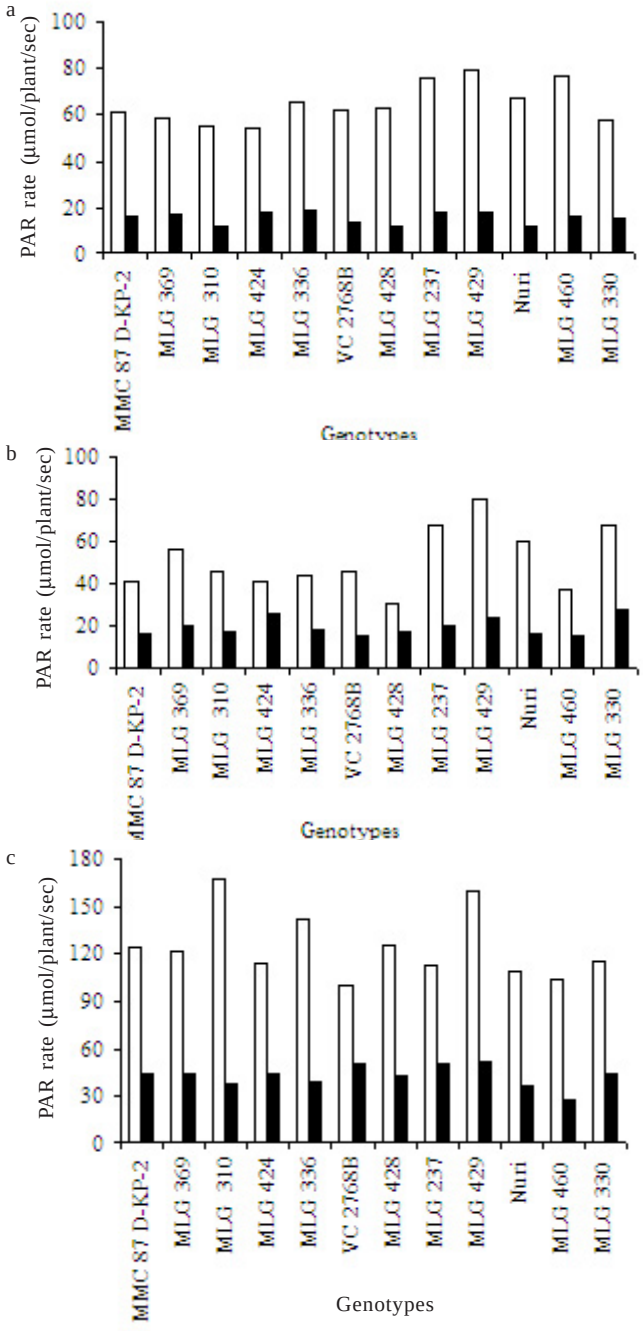

Figure 2. The photosynthetically active radiation (PAR) absorption rate (ì mol/plant/sec) at: (a) 4, (b) 6, and (c) 8 WAP of twelve mungbean genotypes in without shading and 52% shading level. □: without shading, ■: 52% shading.

Table 2. The contrast test of the leaf character inter-group of mungbean genotypes in the 0 and 52% shading level

Quantitative characters	Shading levels				Percentage change (%)	
	0%		52%			
	Tolerant	Sensitive	Tolerant	Sensitive	Tolerant	Sensitive
Leaf number/plant, 4 WAP	14a	15a	12*d*	13*d*	-14.3	-13.3
Leaf number/plant, 6 WAP	26b	30a	18*d*	18*d*	-30.8	-40.0
Leaf number/plant, 8 WAP	25a	25a	17*d*	16*d*	-32.0	-36.0
Leaf area (cm²/plant), 4 WAP	313.8a	329.8a	271.7*d*	238.4*e*	-13.4	-27.7
Leaf area (cm²/plant), 4 WAP	918.1b	1028.9a	724.3*d*	703.7*e*	-21.1	-31.6
Leaf area (cm²/plant), 4 WAP	996.2a	840.4b	758.4*d*	614.4*d*	-23.9	-26.9
SLA (cm²/g), 4 WAP	275.9a	276.9a	370.2*e*	396.7*d*	34.2	43.3
SLA (cm²/g), 6 WAP	211.4a	219.1a	299.5*d*	299.7*d*	41.6	36.8
SLA (cm²/g), 8 WAP	174.5a	180.2a	247.2*d*	239.2*d*	41.7	32.7

in the same line, the number was followed the different letter was significant based on the t test 5%.

by MLG 429 and the lowest was performed by MLG 428 genotype, whereas the highest reducing in eight WAP was reached by MLG 310 genotype and the lowest was reached by VC 2768B genotype (Figure 3b,c).

Photosynthetic rate of the crops was different (Figure 4), at four WAP, photosynthetic rate of MLG 237 and MLG 429 genotypes was increased under the shading treatment, but the other genotypes were reduced (Figure 4a). At six and eight WAP, the highest reduction of photosynthetic rate was performed by MLG 429 and MLG 310 genotypes, and the lowest was found on MLG 428 and VC2768B genotypes (Figure 4b,c).

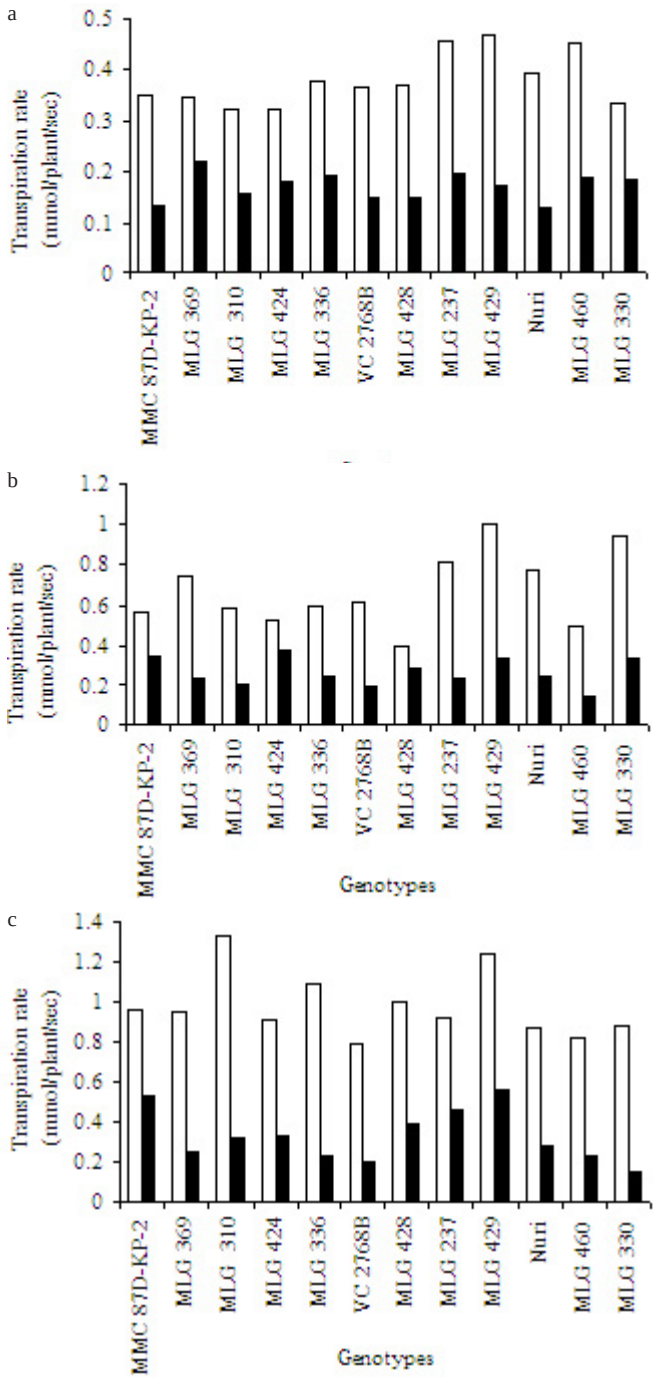

Figure 3. The transpiration rate (mmol/plant/sec) at: (a) 4, (b) 6, and (c) 8 WAP of twelve mungbean genotypes in without shading and 52% shading level. □: without shading, ■: 52% shading.

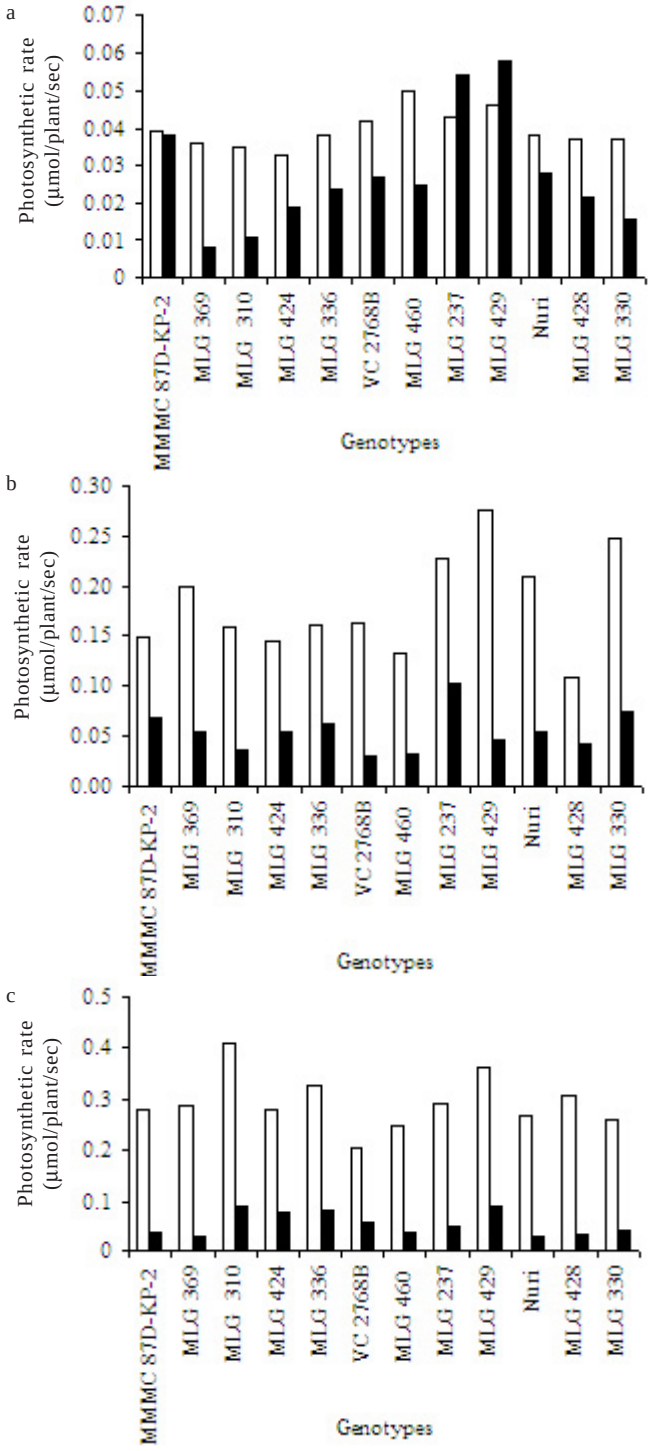

Figure 4. The photosynthesis rate (µmol/plant/sec) at: (a) 4, (b) 6, and (c) 8 WAP of twelve mungbean genotypes in without shading and 52% shading level. □: without shading, ■: 52% shading.

Stomatal CO_2 conductance rate of MLG 369, MLG 310 and MLG 336 genotypes was increased at four WAP. At six WAP, the conductance rate of CO_2 stomata of all genotypes were descended, except for the MLG 424 genotype (Table 3). The highest reduction on conductance rate of CO_2 stomata was reached by the MLG 429 genotype.

Chlorophyll-a content of each genotype was different (Figure 5) caused by different response of the genotypes to shading indicated by different concentration of chlorophyll-a. The content of chlorophyll-a (Figure 5), chlorophyll-b (Figure 6) and the ratio of chlorophyll b/a (Table 4) was affected by the interaction between the genotype and shading.

PAR absorption rate of shading tolerant genotype was higher than that of sensitive genotype (Table 5). The PAR absorption rate of shading tolerant genotype was up to 61.73-74.87%, whereas sensitive genotype was 64.37-78.32%.

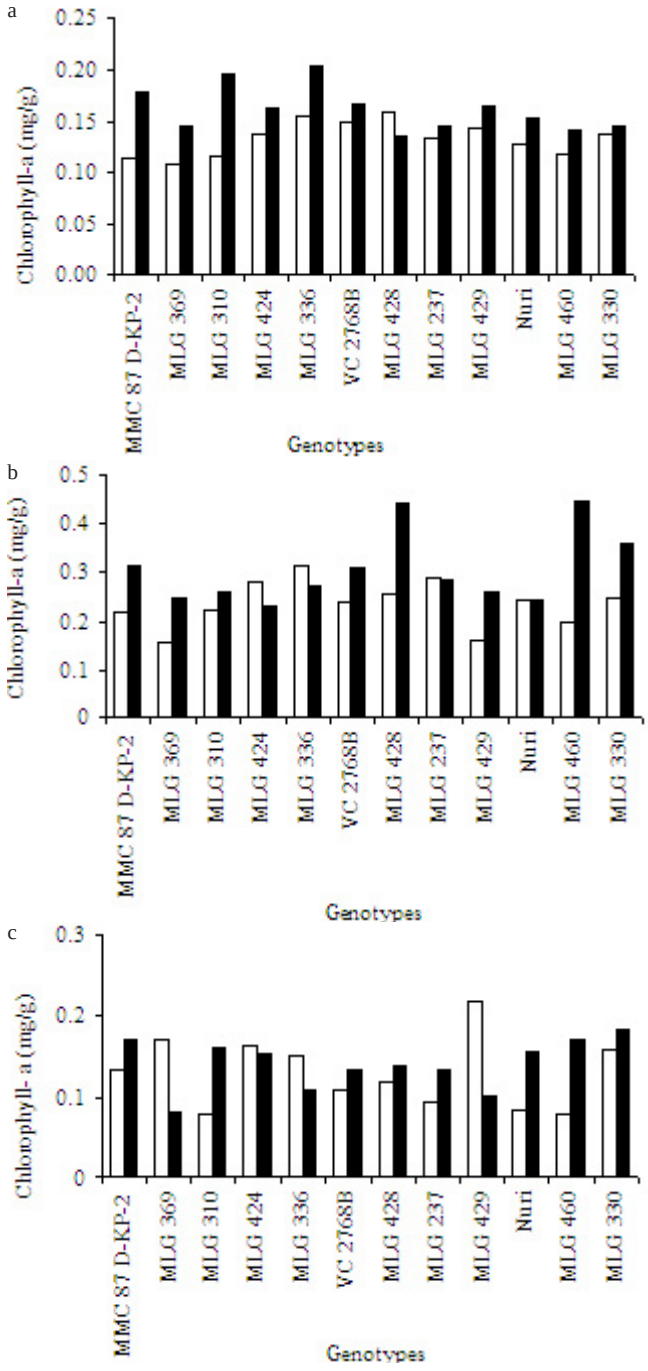

Figure 5. The chlorophyll a content (mg/g leave dry weight) at: (a) 4, (b) 6 and (c) 8 WAP of twelve mungbean genotypes in without shading and 52% shading level. □: without shading, ■: 52% shading.

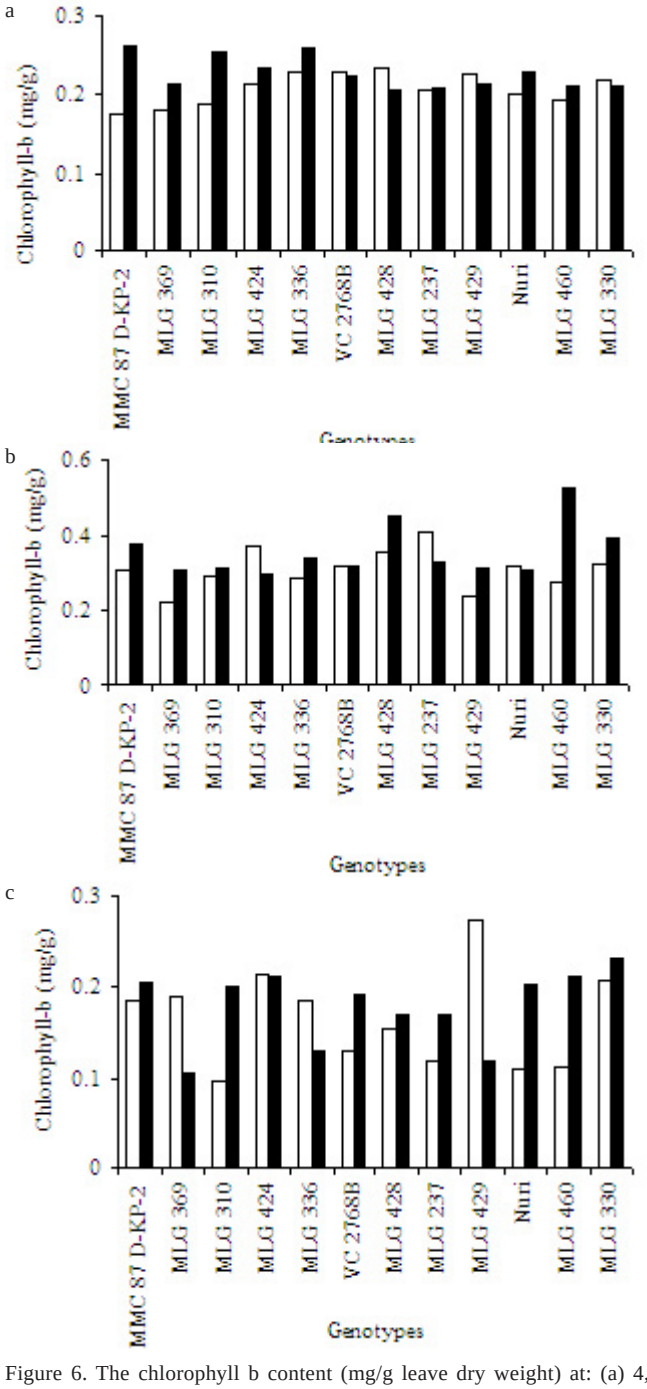

Figure 6. The chlorophyll b content (mg/g leave dry weight) at: (a) 4, (b) 6, and (c) 8 WAP of twelve mungbean genotypes in without shading and 52% shading level. □: without shading, ■: 52% shading.

The contrast analysis showed that the shading treatments caused reducing rate of PAR absorption, transpiration, photosynthesis, and CO_2 stomata conductance (Table 5). The reduction of all parameters in tolerant genotype was smaller than that of sensitive genotype.

DISCUSSION

Leaves were crop photosynthetic apparatus harvesting light energy for the growth and photosyntate production through photosynthesis. Shading could cause reduction of

Table 3. The CO_2 stomatal conductance (mol/plant/sec) of twelve mungbean genotypes at two shading levels

Treatment Shading levels (%)	Genotypes	Age (WAP)		
		4	6	8
0	MMC 87 D-KP-2	0.033abcd	0.071cd	0.028bcde
0	MLG 369	0.026cdef	0.094b	0.026cdef
0	MLG 310	0.025cdef	0.074cd	0.035abc
0	MLG 424	0.024cdefgh	0.067cd	0.024defg
0	MLG 336	0.021defghi	0.076c	0.032abcd
0	VC 2768B	0.028bcde	0.078c	0.021efg
0	MLG 428	0.040ab	0.050e	0.027bcdef
0	MLG 237	0.029bcde	0.103b	0.023defg
0	MLG 429	0.021defghi	0.127a	0.036ab
0	Nuri*	0.019efghij	0.098b	0.023defg
0	MLG 460*	0.034abc	0.063d	0.022efg
0	MLG 330*	0.019efghij	0.119a	0.026cdef
52	MMC 87 D-KP-2	0.009ij	0.047e	0.030bcde
52	MLG 369	0.043a	0.016h	0.011hi
52	MLG 310	0.031abcde	0.031fg	0.022efg
52	MLG 424	0.015fghij	0.073cd	0.018fgh
52	MLG 336	0.026cdef	0.022gh	0.011hi
52	VC 2768B	0.007j	0.035f	0.007i
52	MLG 428	0.013ghij	0.050e	0.024defg
52	MLG 237	0.015fghij	0.020h	0.028bcde
52	MLG 429	0.014fghij	0.039ef	0.039a
52	Nuri*	0.011hij	0.032fg	0.016gh
52	MLG 460*	0.012hij	0.014h	0.011hi
52	MLG 330*	0.014fghij	0.047e	0.005i
Variance coefficient (%)		32.330	12.150	20.830

In the same column, the number was followed the different letter showed was significantly according to the DMRT test 5%; WAP: the week after planted; *: the genotype was sensitive to the shading.

Tablel 4. The chlorophyll b/a ratio of twelve mungbean genotypes at two shading levels

Treatment Shading levels (%)	Genotypes	Age (WAP)		
		4	6	8
0	MMC 87 D-KP-2	1.542fg	1.406c	1.405b
0	MLG 369	1.649a	1.439b	1.118n
0	MLG 310	1.612c	1.296ef	1.230ij
0	MLG 424	1.552f	1.330d	1.301ef
0	MLG 336	1.474i	0.912n	1.223jk
0	VC 2768B	1.524g	1.333d	1.186m
0	MLG 428	1.476i	1.407c	1.314d
0	MLG 237	1.539fg	1.404c	1.271g
0	MLG 429	1.571e	1.485a	1.256h
0	Nuri*	1.574de	1.305e	1.294f
0	MLG 460*	1.631b	1.397c	1.429a
0	MLG 330*	1.591d	1.307e	1.306e
52	MMC 87 D-KP-2	1.466i	1.205i	1.209l
52	MLG 369	1.464i	1.248h	1.314d
52	MLG 310	1.301l	1.194i	1.253h
52	MLG 424	1.430j	1.287f	1.376c
52	MLG 336	1.277m	1.243h	1.201l
52	VC 2768B	1.352k	1.033m	1.423a
52	MLG 428	1.529g	1.017m	1.219k
52	MLG 237	1.430j	1.161k	1.260h
52	MLG 429	1.310l	1.198i	1.191m
52	Nuri*	1.499h	1.266g	1.304e
52	MLG 460*	1.501h	1.178j	1.235i
52	MLG 330*	1.442j	1.088l	1.271g
Variance coefficient (%)		0.680	0.720	0.400

In the same column, the number was followed the different letter showed was significantly according to the DMRT test 5%; WAP: the week after planted; *: the genotype was sensitive to the shading.

Table 5. The contrast test of the physiological characters of inter group mungbean genotypes in the 0 and 52% shading lavels

Quantitative characters	Shading levels				Percentage change (%)	
	0%		52%		Tolerant	Sensitive
	Tolerant	Sensitive	Tolerant	Sensitive		
PAR rate (µmol/plant/sec), 4 WAP	63.83a	67.06a	16.04*d*	14.54*e*	-74.87p	-78.32p
PAR rate (µmol/plant/sec), 6 WAP	50.20b	54.89a	19.21*d*	19.56*d*	-61.73p	-64.37p
PAR rate (µmol/plant/sec), 8 WAP	129.85a	109.68b	45.13*d*	36.10*e*	-65.24q	-67.09p
Transpiration rate (mmol/plant/sec), 4 WAP	0.38a	0.39a	0.17*d*	0.17*d*	-55.26p	-56.41p
Transpiration rate (mmol/plant/sec), 6 WAP	0.65b	0.74a	0.27*d*	0.24*d*	-58.46q	-67.57p
Transpiration rate (mmol/plant/sec), 8 WAP	1.02a	0.86a	0.36*d*	0.22*e*	-64.71p	-74.42p
Photosyntesis rate (µmol/plant/sec), 4 WAP	0.039a	0.042a	0.029*d*	0.023*e*	-25.64q	-45.24p
Photosyntesis rate (µmol/plant/sec), 6 WAP	0.177b	0.197a	0.055*d*	0.054*d*	-68.93q	-72.59p
Photosyntesis rate (µmol/plant/sec), 8 WAP	0.306a	0.260b	0.061*d*	0.034*e*	-80.07p	-86.92p
Currant CO_2 stomata (mol/plant/sec), 4 WAP	0.028a	0.024a	0.019d	0.012e	-32.14p	-50.00p
Currant CO_2 stomata (mol/plant/sec), 6 WAP	0.082b	0.093a	0.037d	0.031d	-54.88q	-66.67p
Currant CO_2 stomata (mol/plant/sec), 8 WAP	0.028a	0.024b	0.021d	0.011e	-25.00p	-54.17p
Chlorophyll a (mg/g leaf dry weight), 4 WAP	0.14a	0.13a	0.170d	0.15e	21.43	15.38
Chlorophyll a (mg/g leaf dry weight), 6 WAP	0.24a	0.23a	0.29e	0.35d	20.83	52.17
Chlorophyll a (mg/g leaf dry weight), 8 WAP	0.14a	0.11b	0.13d	0.17d	-7.14	54.54
Chlorophyll b (mg/g leaf dry weight), 4 WAP	0.21a	0.20a	0.23d	0.22e	9.52	10.00
Chlorophyll b (mg/g leaf dry weight), 6 WAP	0.31a	0.31a	0.34e	0.41d	9.68	32.26
Chlorophyll b (mg/g leaf dry weight), 8 WAP	0.17a	0.14b	0.17e	0.22d	0	57.14
Chlorophyll b/a ratio, 4 WAP	1.540b	1.599a	1.396e	1.479d	-9.35p	-7.50p
Chlorophyll b/a ratio, 6 WAP	1.335a	1.336a	1.179d	1.177d	-11.91p	-11.90p

The number was followed with the same letter to the same line was not significant according to 5% test, WAP: week after planted, PAR: photosynthetically active radiation, the sign of the negative (-) showed the reduction.

leaf number and area. Leaf area reduction had direct impact on reduction photosyntate production. Several researches showed that increasing of leaves area will increase the rate of net photosynthesis (Widiastuti *et al*. 2004; Sulandjari *et al*. 2005).

The different genotypes will response differently to light stress. The shading tolerant mungbean genotypes had good response to light stress so that the growth and development of the leaves were better than that of sensitive genotypes. The shading tolerant mungbean genotypes had bigger and thicker leaves than that of sensitive genotypes. Souza and Valio (2003) also reported that leaf thickness of shading adapted plant could live in light stress condition and the thickness of their leaves was not change. The light stress could be avoided through increasing of interception light efficiency, total light interception by increasing of leaf area, proportion of leaf area per unit plant tissue, and percentage of the light absorbed for photosynthesis. Efficiency of light interception was reached by reducing of reflected and transmitted light through reduction of leaves trichoma number and increasing of chlorophyll content.

Reducing of quantity and the quality of the sunlight will influence crop physiological process on opening and closing of stomata, rate of transpiration, photosynthetic dynamics, and stomatal conductance (Rajapakse *et al*. 1999; Dong & He 2003). Stomatal movements to enable gas exchange with the atmosphere are mainly controlled by light. The exchange of water vapour, CO_2, and O_2 is limited to stomatal pores, which are minute intercellular openings bounded by two kidney-shaped specialized epidermis cells called the guard cells (Bolhar-Nordenkampf & Draxler 1993). When the transpiration rate was higher, the stomata was closed. In this condition, CO_2 that entered decreased, and the photosynthesis rate would be descend. Under conditions of high rates of transpiration, the leaves may temporarily wilt and close their stomata. At times entry of CO_2 is reduced, and the rate of photosynthesis will drop.

The rate of the photosynthesis is influenced by light intensity, CO_2 concentration and temperature. Photosynthesis does not occur in the absence of light, but as the intensity of irradiation will increase the rate of photosynthesis. The rate of the photosynthesis will reduce as well as the shading level is increased (Islam *et al.* 1999; de Alvarenga *et al.* 2003). Reducion of the sunlight will reduce the rate of photosynthesis. The sunllight was the main energy source in the photosynthesis process, so that the light intensity could control photosynthesis (Xu & Shen 1999). Light radiation influences the growth and development of the crop through photosynthesis. Plants growing under shade exhibits lower biomass production compared with plants growing under higher irradiance (Huante & Rincon 1998).

Radiant energy with wavelength of 400-700 nm plays an important role in the photosynthesis process. Therefore, rate of the PAR absorption was increased as well as the photosynthesis rate. Green plants capture solar energy and convert it into chemical energy by the photosynthesis process. During photosynthesis, CO_2 and water are transformed into simple carbohydrates and oxygen gas.

The leaves of plants are photosynthetically active organ, which are able to store absorbed solar energy in reduced organic compounds (Bolhar-Nordenkampf & Draxler 1993). The wider and flat leaf surface were enabled to maximize absorption of light by increasing of leaf area (Jones & McLeod 1990).

All the photosynthetic cells contained one or more the chlorophyll. In the process of photosynthesis, chlorophyll

played in the light energy absorption and change this energy into the chemical energy in the photosynthesis process (Bolhar-Nordenkampf & Oquist 1993).

Chlorophyll is green pigments, which plays in the light energy absorption. There are several kinds of chlorophyll i.e. chlorophyll a, b, c, and d, however, the most abundant are chlorophyll-a ($C_{55}H_{72}O_5N_4Mg$) and -b ($C_{55}H_{70}O_6N_4Mg$). Chlorophyll-a is dark green in color, whereas chlorophyll-b is light green. The shading could increase content of chlorophyll-a and -b per dry weight of leaves (Goncalves *et al*. 2001; Danesi *et al*. 2004). Increasing of chlorophyll content was a mechanism in order to increase the light interception to maintain normal life of the crop under shading condition. This increased content of the chlorophyll was to enhance efficiency of the PAR absorption indicating adaptation of crops to the low light intensity (Cartechini & Palliotti 1995). Two mechanisms of plant to avoid low light intensity are by increasing the total light absorption for the photosynthesis process, and by reducing reflected and transmitted light.

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