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RESEARCH ARTICLE

Analysis of morphological characters in soybean plants submitted to different levels of artificial shading

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ABSTRACT

Morphological characters of soybean can be influenced by shading which are occasionally caused in plants. Thus, this study aimed to evaluate the effect of different shading levels on epicotyl length, epicotyl diameter and height of soybean plants. The experiments were conducted in a greenhouse. When the plants reached the V2 development stage, measurements were taken of epicotyl length and epicotyl diameter in experiment I (conducted in autumn); and epicotyl length, epicotyl diameter, and plant height in experiments II (spring/summer) and III (summer). Each experiments were conducted in a randomized block design, in subdivided plots, with four repetitions. The plots were composed of four shading levels and the subplots were composed of eight conventional cultivars. Each experimental unit consisted of one plant grown in a 3 dm^3 pot filled with soil and organic matter. The three characters evaluated in the experiment presented significant effect for the interaction cultivar x shading x sowing seasons. Epicotyl length, independent of the sowing season, increased as the shading level intensified. Both the shading level and the sowing season influenced the diameter of the epicotyl, in a general way, reducing the diameter as the shading level increased. With increasing shading rate there was an increase in plant height. Moreover, the cultivars formed statistically distinct groups for the three morphological characters evaluated.

Keywords: *Glycine max*, DHS, plant breeding, solar radiation, photosynthesis, light incidence.

INTRODUCTION

Soybean (*Glycine max* (L.) Merr.) is native of East Asia and was introduced in Brazil in 1882. However, at that time, the development of the crop was not successful because it was initially cultivated in Bahia, where the latitude is different from its region of origin (Sediyama et al., 2009). When cultivated in Rio Grande do Sul, the plants found favorable edaphoclimatic conditions for their development and with the development of research in fertility and genetic improvement soybean plantation became possible throughout the Brazilian territory (Bezerra et al., 2015; Ferreira, Carvalho, Lautenchleger, & Loro, 2022a; Ferreira, Carvalho, & Loro, 2022b; Ferreira, Carvalho, Loro, & Lautenchleger, 2022c).

The soybean crop stands out internationally due to its protein and oil content, being possible its use mainly in human and animal food and biofuel production (Bezerra et al., 2015), for being responsible for 90% of the production of vegetable oils in Brazil, soybean has a large participation in the Brazilian trade balance (Bezerra et al., 2015). Soybeans, like other crops, have maximum yield potential. However, the environment imposes a series of limitations to the genotype and, consequently, to the yield, which is often lower than the potential (Weber, 1968). In this context, the use of light is the most important process for productivity, because it is through photosynthesis that the plant accumulates organic matter in its tissues (Melges et al., 1989).

Solar radiation is related, besides photosynthesis, to the elongation of the main stem and branches, leaf expansion, pod and grain setting and biological fixation in soybean culture (Câmara, 2000). Artificial shading in soybeans shows a reduction in dry matter and seed production (Schou et al., 1978) and in studies of soybean performance in agroforestry systems (soybean and macauba) the growth and productivity characteristics of the soybean crop were influenced by the shading caused by macauba (Avelino et al., 2023).

In a system of intercropping of soybean with corn, the soybean plants presented higher lodging when intercropped in comparison with monocropping (Alvarenga et al., 1998). According to Mohtha and De (1980), these higher values obtained in the intercropping systems are considered normal and occur due to the shading caused by corn, causing the soy plants to stretch. One of the explanations for the stretching is that the photodegradation of auxins, responsible for cell elongation, maintains a hormonal balance that causes the plant to grow normally under the incidence of natural light (Valio, 1979). Therefore, when there is a decrease in light incidence, due to shading, hormonal imbalance occurs resulting from the non-degradation of auxins, whose higher concentration in meristematic regions results in greater plant growth (Valio, 1979). However, a new agronomic approach in the soybean-corn intercropping system provided an increase in dry matter, flower number, and seed yield of the soybean crop (Raza et al., 2019).

To request protection for a cultivar, one must follow the Cultivar Protection Law (Law n. 9.456, regulated by the Decree no. 2.366, of November 5, 1997), which details one of the tests, the DHS (Distinctiveness, Homogeneity and Stability) (Brazil, 1997). This test consists in the evaluation of a series of morphological characteristics in the different stages of plant development, which are called minimum descriptors, specific for each species and recommended by the National Service for Plant Variety Protection (SNPC) (Brazil, 1997). The minimum descriptors recommended for soybeans consist of morphological characteristics to be evaluated in seeds, seedlings and adult plants and, for special purposes, additional evaluations such as protein and enzyme electrophoresis (Brazil, 1997).

The number of descriptors recommended for soybean, which totaled thirty-eight, has been insufficient and new descriptors are being evaluated (Nogueira et al., 2008). The aforementioned authors, reported the length of the hypocotyl and epicotyl, among others, as useful characters to distinguish soybean genotype. Matsuo et al. (2012) characterized the influence of the genetic component on the phenotypic expression of hypocotyl and epicotyl length in soybean genotypes, i.e., high genetic influence.

Thus, the objective was to evaluate morphological characters in soybean plants submitted to different levels of shading.

MATERIAL AND METHODS

The experiments were conducted under greenhouse conditions at the Federal University of Viçosa - Rio Paranaíba Campus, located in Rio Paranaíba, State of Minas Gerais (19° 11' 39'' S; 46° 14' 37'' W; 1133 msnm). During the period of the experiments, the necessary plant management was performed to maintain an optimal state for soybean growth, following recommendations by Sediyama (2009) and Sediyama et al. (2015).

On benches, plastic pots with a capacity of 3 dm^3 were filled with soil and organic matter in a 3:1 ratio. Eight seeds were sown per pot, using a manual soil furrower (drill) to allocate the seeds at a depth of 2 cm. After the emergence (Stage VE, according to Fehr & Caviness, 1977) the plants were thinned, in order to keep one seedling per pot.

When the plants reached the V2 development stage, the epicotyl length (in mm), epicotyl diameter (in mm, in the central position of the epicotyl between the node of the unifoliate leaves and the node of the first trifoliolate leaf) were measured in the experiment conducted in May/2019 (autumn); and the epicotyl length (in mm), epicotyl diameter (in mm) and plant height (in mm), in the experiments conducted in October/2019 (spring/summer) and February/2020 (summer). For the evaluations, a digital pachymeter was used, considering two decimal places.

In each of the sowing seasons (May/2019, October/2019 and February/2020), the design was randomized block design, in a subdivided plot scheme, with four repetitions (blocks). Each plot was composed of four shading levels (0 %, 30 %, 50 % and 70 % shading) and the subplots were composed of eight conventional soybean cultivars (BRS 283, BRS 284, MG/BR 46 (Conquista), BRSGO 8660, TMG 4185, TMG 4182, BRSGO 7560 and FT-Cristalina). The experimental unit was one plant, grown in a pot. In the treatments of 30%, 50% and 70% shading, black screens of the shading type were used to provide a reduction of the incident solar radiation. The screens were fixed on a movable frame, made of iron and wood, which allowed them to be raised as the plants grew, always maintaining a distance of 50 cm between the apex of the plant and the screen. The artificial shading was installed on the sowing date and maintained until the end of the evaluations.

The data was analyzed using the joint analysis of variance of the experiments, considering the following model:

$$y_{ijk} = m + b/a_{jk} + p_i + pa_{ik} + erro_a + s_j + sa_{ik} + ps_{ij} + psa_{ijk} + erro_b$$

Where, *y* is the value of the character; *m* is the overall average of the experiments; *b/a* is the effect of blocks within environments (sowing seasons); *p* is the effect of plot; *pa* is the effect of the interaction plot x environments (sowing seasons); *s* is the effect of sub-plot; *sa* is the effect of the interaction sub-plot x environments (sowing seasons); *ps* is the effect of the interaction sub-plot x plot; and *psa* is the effect of the interaction plot x sub-plot and environments (sowing seasons).

The cultivars were grouped using the Scott-Knott test, the sowing seasons were compared using the Tukey test, and the levels of shading were studied using regression analysis. For the statistical analyses 5% significance was considered and the SAEG (2007) program was used.

RESULTS AND DISCUSSION

The characters, epicotyl length and plant height, showed significant effect for all sources of variation. Epicotyl diameter, for the shading x season source, was not significant. The values of coefficient of variation in the plot were 30.77% and 14.16% in the subplot in epicotyl length, 11.99% in the plot and 8.48% in the subplot in epicotyl diameter and coefficient of variation in the plot 20.16% and coefficient of variation in the subplot 11.04% in plant height (Table 1).

Table 1. Summary of analysis of variance of epicotyl length, epicotyl diameter and plant height measured, in mm, at the V2 development stage in experiments conducted in different seasons (DS), shading levels (SL) and cultivars (CULT).

FV	Epicotyl length			Epicotyl diameter			Plant height		
	DF	MS[1]		DF	MS[1]		DF	MS[1]	
Block/EP	9	920.172		9	0.262		6	1911.631	
DS	2	5776.737	**	2	1.107	**	1	123941.800	**
SL	3	79152.060	**	3	12.200	**	3	272398.000	**
SL*DS	6	3174.195	**	6	0.137	ns	3	33292.570	**
Resídue (a)	27	433.464		27	0.101		18	938.548	
CULT	7	12579.530	**	7	0.815	**	7	30558.660	**
CULT*DS	14	176.518	*	14	0.205	**	7	706.642	*
CULT*SL	21	538.207	**	21	0.188	**	21	2430.890	**
CULT*SL*DS	42	154.575	**	42	0.147	**	21	1648.590	**
Resídue (b)	252	91.777		252	0.051		168	281.263	
Overall average		67.66			2.65			151.93	
$VC_{(\%)plot}$		30.77			11.99			20.16	
$VC_{(\%)sub\text{-}plot}$		14.16			8.48			11.04	

[1] **, * e ns: Significant at 1%, 5% probability and not significant, respectively; VC: Variation coefficient.

The behavior of the characters was not influenced in isolation by a single source of variation, which was studied, but by the interactions among them. The values of the coefficient of variation found in the present work corroborate with those presented by Nogueira et al. (2008), Matsuo et al. (2012), Camargos et al (2019) and Hanyu et al. (2020). According to Nogueira et al. (2008) the high values of coefficient of variation, for the epicotyl length may be associated with the non-homogenization of the characteristics throughout the development process of the cultivars.

The epicotyl length of the soybean cultivars in the different seasons were allocated into statistically distinct groups, except for sowing in May/2019 (Table 2). The existence of genetic variability is a necessary condition for a trait to be useful in differentiating cultivars (Nogueira et al., 2008) and the magnitudes of the genotypic determination coefficients (H^2) were greater than 85% in Nogueira et al. (2008) and greater than 80% in Matsuo et al. (2012) and Hanyu et al. (2020). According to Cruz (2005) H^2 is a measure analogous to heritability and expresses the phenotypic variance due to genetic variability among treatment means, so that high estimates of H^2 indicate that most of the variation among genotype means is genetic in nature (Vencovsky, 1987).

Table 2. Average epicotyl length, in mm, obtained in soybean plants, V2 development stage, in eight cultivars as a function of three sowing times for four levels of shading (0%, 30%, 50% and 70%).

Cultivars	May/2019		October/2019		February/2020	
---------- 0 % of shading ----------						
BRS 283	29.25	Aa[1]	34.74	Ab	28.56	Ab
BRS 284	35.25	Aa	40.17	Aa	39.23	Ab
MG/BR 46 (Conquista)	38.50	Aa	44.41	Aa	36.03	Ab
BRSGO 8660	30.25	Aa	31.52	Ab	32.28	Ab
TMG 4185	46.50	Aa	47.25	Aa	38.62	Ab
TMG 4182	36.25	Aa	40.21	Aa	43.28	Aa
BRSGO 7560	35.00	Ba	53.56	ABa	55.93	Aa
FT-Cristalina	21.50	Aa	25.55	Ab	22.46	Ab
---------- 30 % of shading ----------						
Cultivars	May/2019		October/2019		February/2020	
BRS 283	39.50	Ad	40.63	Ac	47.97	Ab
BRS 284	62.50	Ab	57.99	Ab	57.95	Ab
MG/BR 46 (Conquista)	76.25	Ba	57.20	Cb	81.72	Aa
BRSGO 8660	53.25	Ac	52.16	Ab	55.90	Ab
TMG 4185	79.25	Aa	76.27	Aa	74.56	Aa
TMG 4182	69.00	Ab	56.83	Ab	68.04	Aa
BRSGO 7560	88.50	Aa	78.88	Aa	84.89	Aa
FT-Cristalina	35.75	Ad	33.73	Ac	34.37	Ac
---------- 50 % of shading ----------						
Cultivars	May/2019		October/2019		February/2020	
BRS 283	53.25	Ad	48.22	Ab	51.83	Ac
BRS 284	62.75	Ac	54.23	Ab	72.16	Ab
MG/BR 46 (Conquista)	80.75	Ab	79.87	Aa	87.18	Aa
BRSGO 8660	69.75	Ac	48.32	Bb	54.76	ABc
TMG 4185	105.75	Aa	72.90	Ba	84.13	Ba
TMG 4182	72.75	Ac	68.34	Aa	67.62	Ab
BRSGO 7560	92.00	Ab	76.82	Aa	83.26	Aa
FT-Cristalina	36.25	Ae	35.84	Ac	39.59	Ad
---------- 70 % of shading ----------						
Cultivars	May/2019		October/2019		February/2020	
BRS 283	106.25	Ad	65.29	Bd	90.50	Ac
BRS 284	116.25	Ad	86.47	Bb	112.14	Ab
MG/BR 46 (Conquista)	144.00	Ab	95.44	Ba	127.93	Ab
BRSGO 8660	109.75	Ad	83.73	Bb	99.18	ABc
TMG 4185	147.00	Ab	108.98	Ba	119.75	Bb
TMG 4182	130.00	Ac	78.63	Cc	105.57	Bc
BRSGO 7560	170.50	Aa	101.36	Ca	145.94	Ba
FT-Cristalina	79.25	Ae	55.14	Bd	69.05	ABd

[1]In each shading season, means followed by the same capital letters in the horizontal line do not differ at 5% significance using the Tukey test; means followed by the same small letters in the vertical line, within each sowing season, form statistically similar groups using the Scott-Knott grouping test, at 5% significance.

The cultivar FT-Cristalina, regardless of the level of shading and the sowing season showed the lowest values of epicotyl length, i.e., it was allocated in the group with the lowest average. For the other groups of averages, a variation in the behavior of the cultivars was observed. For hypocotyl length, Alves et al. (2019) reported that the cultivars BRS810C, BRSMG760SRR, TMG1175RR and BMX Tornado RR presented lower averages in relation to the other cultivars analyzed, high stability and general adaptability; while the cultivar BG4272 presented higher average, high stability and general adaptability. The identification of soybean cultivars with predictable and stable behavior, regarding hypocotyl length, contributes to soybean improvement in terms of better knowledge of the potential descriptor and the possibility of increasing the number of descriptors (Alves et al., 2019).

For the shading levels of 0%, 30%, and 50% there was a tendency for the epicotyl length of some cultivars to differ between the sowing seasons. With 0% shading, the cultivar BRSGO7560 had lower average in May/2019 and higher in February/2020; with 30% shading the cultivar MG/BR 46 (Conquista) had lower average in October/19 and higher in February/20; and with 50% shading the cultivars BRSGO8660 and TMG4185 showed, in general, lower average in October/2019 and higher in May/2019. For the 70% shading level, in general, the cultivars showed less epicotyl length in the October/2019 sowing and greater values were identified in May/2019 (Table 2).

Analyzing the sowing seasons, the magnitude of the epicotyl length increased as the shading intensity increased, within the limits studied in the present work. More pronounced increases were identified in May/2019, followed by February/2020 and October/2019. In general, and also in the present work, the epicotyl length was influenced by the shading level, the sowing season and the cultivar analyzed (Table 3 and Figure 1).

For epicotyl diameter, statistically distinct groups were identified for all levels of shading in the October sowing (conventional soybean sowing season in most soybean producing regions) and only for some shading levels in other sowing seasons (Table 4). When fixing the shading level and analyzing the behavior of this character it could be observed that at 0% shading the cultivars BRS284 and MG/BR 46 (Conquista) showed different averages between October/2019 compared to May/2019 or February/2020. For 30%, no cultivar differed between October/2019 and other sowing seasons. At 50% shade, two cultivars (BRSGO 7560 and FT-Cristalina) showed a difference between October/2019 and other sowing seasons. At 70% shading, 5 of the 8 cultivars showed different averages when compared to the sowing seasons, always towards a higher average in October/2019 compared to May/2019 or February/2020.

The cultivars that had the simple linear regressions as the best equation to explain the behavior of the epicotyl diameter as a function of the levels of shading, the greatest rate of reduction was 0.02 mm for each % of shading that was added, within the range studied. In the sowing in May/2019 the cultivars that had the behavior explained by the multiple linear regression (second degree) presented the maximum point of the equations ranging from 13% to 21% shading and for sowings in October/19 and February/2020 the maximum points were, respectively, equal to 11% and approximately 39% (Table 5). Thus, for the cultivars whose equations that best fit the second-degree equations, there was a reduction in the diameter of the epicotyl with the increase in the level of shading, within the limits studied in this work, from the maximum point of each cultivar.

Table 3. Plant behavior regarding the epicotyl length of soybean cultivars as a function of shading levels, evaluated at the V2 development stage, separately for the different sowing seasons.

Cultivars	Exponential model equation	r^2
------ May/2019 ------		
Cultivars	Exponential model equation	r^2
BRS 283	$26.1054 \times 1.0178^{SOM}$	0.9089
BRS 284	$35.2907 \times 1.0157^{SOM}$	0.9122
MG/BR 46 (Conquista)	$39.5476 \times 1.0177^{SOM}$	0.9445
BRSGO 8660	$30.1995 \times 1.0181^{SOM}$	0.9935
TMG 4185	$47.1618 \times 1.0165^{SOM}$	0.9983
TMG 4182	$36.9122 \times 1.0171^{SOM}$	0.9414
BRSGO 7560	$37.7694 \times 1.0214^{SOM}$	0.9362
FT-Cristalina	$20.4805 \times 1.0170^{SOM}$	0.8747
------ October/2019 ------		
Cultivares	Exponential model equation	r^2
BRS 283	$33.0613 \times 1.0088^{SOM}$	0.9366
BRS 284	$39.9724 \times 1.0097^{SOM}$	0.8409
MG/BR 46 (Conquista)	$43.3731 \times 1.0114^{SOM}$	0.9813
BRSGO 8660	$31.8302 \times 1.0125^{SOM}$	0.8630
TMG 4185	$48.7181 \times 1.0109^{SOM}$	0.8933
TMG 4182	$41.2098 \times 1.0097^{SOM}$	0.9880
BRSGO 7560	$55.3707 \times 1.0084^{SOM}$	0.9018
FT-Cristalina	$24.6899 \times 1.0102^{SOM}$	0.9075
------ February/2020 ------		
Cultivares	Exponential model equation	r^2
BRS 283	$28.3191 \times 1.0155^{SOM}$	0.9421
BRS 284	$38.0023 \times 1.0146^{SOM}$	0.9779
MG/BR 46 (Conquista)	$39.6725 \times 1.0174^{SOM}$	0.9315
BRSGO 8660	$32.4004 \times 1.0147^{SOM}$	0.9000
TMG 4185	$40.9751 \times 1.0157^{SOM}$	0.9633
TMG 4182	$43.7411 \times 1.0117^{SOM}$	0.9132
BRSGO 7560	$54.8656 \times 1.0124^{SOM}$	0.8756
FT-Cristalina	$21.6347 \times 1.0152^{SOM}$	0.9458

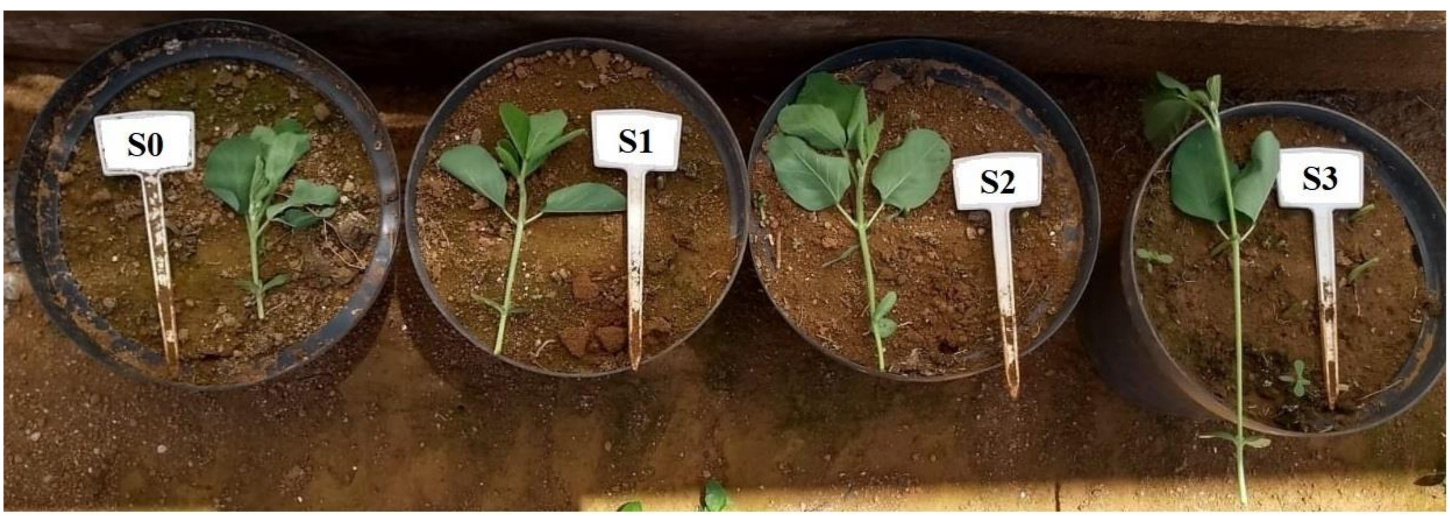

Figure 1. Epicotyl length of cultivar TMG 4185 as a function of four artificial shading levels (S0 = 0%, S1 = 30%, S2 = 50% and S3 = 70% shading).
Photo taken by: Willian Daniel dos Reis Gontijo.

Table 4. Average of epicotyl diameter, in mm, obtained from soybean plants at the V2 development stage in eight cultivars as a function of three sowing times for four levels of shading (0%, 30%, 50% and 70%).

Cultivars	May/2019	October/2019	February/2020
---------- 0 % of shading ----------			
BRS 283	2.98 Aa[1]	3.34 Aa	3.22 Aa
BRS 284	2.99 Ba	3.46 Aa	3.14 ABa
MG/BR 46 (Conquista)	3.02 Aa	2.99 Ab	1.54 Bb
BRSGO 8660	3.03 Aa	3.17 Ab	3.37 Aa
TMG 4185	2.72 Aa	2.87 Ab	2.99 Aa
TMG 4182	3.21 Aa	3.13 Ab	3.21 Aa
BRSGO 7560	2.81 Aa	3.01 Ab	3.02 Aa
FT-Cristalina	2.93 Aa	3.02 Ab	3.17 Aa
---------- 30 % of shading ----------			
Cultivars	May/2019	October/2019	February/2020
BRS 283	2.93 Aa	3.20 Aa	2.88 Aa
BRS 284	3.07 Aa	2.92 Ab	2.90 Aa
MG/BR 46 (Conquista)	2.68 Ab	2.49 Ac	2.44 Aa
BRSGO 8660	2.94 Aa	2.82 Ab	2.68 Aa
TMG 4185	2.65 Ab	2.61 Ac	2.67 Aa
TMG 4182	2.61 Ab	2.62 Ac	2.68 Aa
BRSGO 7560	2.76 Ab	2.86 Ab	2.58 Aa
FT-Cristalina	2.98 Aa	2.85 Ab	2.70 Aa
---------- 50 % of shading ----------			
Cultivars	May/2019	October/2019	February/2020
BRS 283	2.93 Aa	2.99 Aa	2.83 Aa
BRS 284	2.59 Aa	2.93 Aa	2.61 Aa
MG/BR 46 (Conquista)	2.45 Aa	2.46 Ab	2.47 Aa
BRSGO 8660	2.74 Aa	2.82 Aa	2.62 Aa
TMG 4185	2.65 Aa	2.62 Ab	2.61 Aa
TMG 4182	2.68 Aa	2.54 Ab	2.67 Aa
BRSGO 7560	2.42 ABa	2.65 Ab	2.22 Bb
FT-Cristalina	2.71 ABa	2.97 Aa	2.51 Ba
---------- 70 % of shading ----------			
Cultivars	May/2019	October/2019	February/2020
BRS 283	2.03 Ba	2.43 Aa	2.28 ABa
BRS 284	2.12 ABa	2.50 Aa	1.93 Ba
MG/BR 46 (Conquista)	2.18 Aa	2.31 Aa	2.04 Aa
BRSGO 8660	1.98 Ba	2.37 Aa	1.85 Ba
TMG 4185	2.06 Aa	2.20 Ab	2.08 Aa
TMG 4182	2.13 Aa	1.98 Ab	2.08 Aa
BRSGO 7560	2.06 Ba	2.53 Aa	2.11 Ba
FT-Cristalina	2.03 Ba	2.46 Aa	2.24 ABa

[1]Within each shading season, averages followed by the same capital letters in the horizontal axis are not different from each other at 5% significance level by Tukey's test. Averages followed by the same small letters in the vertical axis, within each sowing season, form statistically similar groups by the Scott-Knott grouping test, at 5% significance level.

Table 5. Plant behavior regarding epicotyl diameter of soybean cultivars as a function of shading levels, evaluated at the V2 development stage, separately for the different sowing seasons.

-- May/2019 --		
Cultivars	Equation	r^2
BRS 283	$3.9412 + 0.0168 \times SOM - 0.0004 \times SOM^2$	0.9067
BRS 284	$3.0011 + 0.0097 \times SOM - 0.0003 \times SOM^2$	0.9766
MG/BR 46 (Conquista)	$3.0269 - 0.0119 \times SOM$	0.9976
BRSGO 8660	$3.0108 + 0.0107 \times SOM - 0.0004 \times SOM^2$	0.9792
TMG 4185	$2.6914 + 0.0096 \times SOM - 0.0003 \times SOM^2$	0.8995
TMG 4182	$3.1802 - 0.0140 \times SOM$	0.8844
BRSGO 7560	$2.9183 - 0.0108 \times SOM$	0.8624
FT-Cristalina	$2.9260 + 0.0142 \times SOM - 0.0004 \times SOM^2$	0.9963
-- Outubro/2019 --		
Cultivars	Equation	r^2
BRS 283	$3.4512 - 0.0123 \times SOM$	0.8456
BRS 284	$3.4251 - 0.0126 \times SOM$	0.9179
MG/BR 46 (Conquista)	$2.9089 - 0.0093 \times SOM$	0.8844
BRSGO 8660	$3.1844 - 0.0104 \times SOM$	0.8955
TMG 4185	$2.8959 - 0.0085 \times SOM$	0.8543
TMG 4182	$3.1375 - 0.0153 \times SOM$	0.9434
BRSGO 7560	$3.0230 - 0.0071 \times SOM$	0.9789
FT-Cristalina	$2.9930 + 0.0044 \times SOM - 0.0002 \times SOM^2$	0.7697
--- Fevereiro/2020 ---		
Cultivars	Equation	r^2
BRS 283	$3.2653 - 0.0123 \times SOM$	0.8907
BRS 284	$3.2667 - 0.0166 \times SOM$	0.8869
MG/BR 46 (Conquista)	$3.3727 - 0.0200 \times SOM$	0.8636
BRSGO 8660	$3.3831 - 0.0201 \times SOM$	0.9282
TMG 4185	$3.0349 - 0.0119 \times SOM$	0.9282
TMG 4182	$3.2128 - 0.0148 \times SOM$	0.8945
BRSGO 7560	$2.9868 - 0.0135 \times SOM$	0.9712
FT-Cristalina	$3.1403 - 0.0130 \times SOM$	0.9920

The cultivars analyzed for epicotyl diameter were influenced by the sowing seasons and the level of shading and their interactions. And, for the height of plants, in at least two distinct groups in the two sowing seasons (October/2019 and February/2020). The cultivar BRSGO7560 was allocated to the group with the highest mean values and FT-Cristalina was allocated to the group with the lowest mean values. When analyzing the difference between the averages of cultivars among the sowing seasons within each shading level, it was observed that at 0%, 30%, 50% and 70% the number of cultivars that presented distinct averages were, respectively, equal to 1, 4, 6 and 8 cultivars. With the exception of 0% shading, the cultivars showed lower averages in October/2019 compared to February/2020 (Table 6).

There was an increase in plant height with the increase in shading rate, within the range of the studied interval, and more pronounced increments were observed in February/2020 compared to that of October/2019 (Table 7).

Table 6. Average plant height, in mm, obtained in soybean plants, V2 development stage, in eight cultivars as a function of three sowing seasons for four levels of shading (0%, 30%, 50% and 70%).

Cultivars	October/2019		February/2020	
---------- 0 % of shading ----------				
BRS 283	77.78	Ab[1]	79.41	Ac
BRS 284	83.09	Ab	96.52	Ab
MG/BR 46 (Conquista)	102.15	Aa	59.49	Bc
BRSGO 8660	66.90	Ab	86.69	Ab
TMG 4185	92.85	Aa	96.04	Ab
TMG 4182	81.63	Ab	97.99	Ab
BRSGO 7560	113.13	Aa	120.15	Aa
FT-Cristalina	55.55	Ab	59.75	Ac
---------- 30 % of shading ----------				
Cultivars	October/2019		February/2020	
BRS 283	95.03	Bc	132.98	Ac
BRS 284	125.36	Ab	144.50	Ac
MG/BR 46 (Conquista)	138.00	Bb	201.88	Aa
BRSGO 8660	111.20	Ac	131.45	Ac
TMG 4185	135.26	Bb	163.92	Ab
TMG 4182	113.80	Bc	152.33	Ab
BRSGO 7560	174.25	Aa	197.13	Aa
FT-Cristalina	73.83	Ad	99.23	Ad
---------- 50 % of shading ----------				
Cultivars	October/2019		February/2020	
BRS 283	105.98	Bc	134.60	Ab
BRS 284	133.40	Bb	167.28	Aa
MG/BR 46 (Conquista)	159.35	Aa	176.37	Aa
BRSGO 8660	103.70	Bc	142.64	Ab
TMG 4185	140.25	Bb	188.02	Aa
TMG 4182	129.55	Bb	167.87	Aa
BRSGO 7560	164.15	Aa	185.12	Aa
FT-Cristalina	84.51	Bc	113.43	Ac
---------- 70 % of shading ----------				
Cultivars	October/2019		February/2020	
BRS 283	152.48	Bd	266.75	Ac
BRS 284	211.75	Bb	277.63	Ac
MG/BR 46 (Conquista)	200.75	Bb	382.50	Aa
BRSGO 8660	166.78	Bc	215.52	Ad
TMG 4185	202.25	Bb	350.00	Ab
TMG 4182	182.23	Bc	259.93	Ac
BRSGO 7560	252.50	Ba	397.75	Aa
FT-Cristalina	128.20	Be	221.00	Ad

[1]Within each shading season, averages followed by the same capital letters in the horizontal axis are not different from each other at 5% significance level by Tukey's test; averages followed by the same small letters in the vertical axis, within each sowing season, form statistically similar groups by the Scott-Knott grouping test, at 5% significance level..

Therefore, additional studies are important to increase the knowledge about the development of the length and diameter of the epicotyl and plant height, at the V2 stage, at the recommended time of conventional cultivation, by analyzing other cultivars (genotypes), in advance and delayed sowing and in other environments (soybean growing locations). This is because, for a character to be considered a descriptor of the culture, it must meet the DHS criteria, and a distinct cultivar is considered one that can be clearly distinguished from any other whose existence on the date of the protection request is recognized (Campos et al., 2009).

Table 7. Behavior of plant height of soybean cultivars as a function of shading levels, evaluated separately at the V2 development stage for different sowing seasons.

	-- October/2019--	
Cultivares	Exponential model equation	r^2
BRS 283	$74.4211 \times 1.0091^{SOM}$	0.9184
BRS 284	$82.1902 \times 1.0125^{SOM}$	0.9382
MG/BR 46 (Conquista)	$102.2681 \times 1.0095^{SOM}$	0.9947
BRSGO 8660	$68.6246 \times 1.0118^{SOM}$	0.8725
TMG 4185	$93.2567 \times 1.0104^{SOM}$	0.9400
TMG 4182	$80.6083 \times 1.0110^{SOM}$	0.9753
BRSGO 7560	$114.9688 \times 1.0103^{SOM}$	0.8727
FT-Cristalina	$53.3912 \times 1.0114^{SOM}$	0.9445
	-- February/2020--	
Cultivares	Exponential model equation	r^2
BRS 283	$77.3286 \times 1.0159^{SOM}$	0.8942
BRS 284	$93.4007 \times 1.0144^{SOM}$	0.9537
MG/BR 46 (Conquista)	$67.9219 \times 1.0246^{SOM}$	0.8793
BRSGO 8660	$85.5008 \times 1.0123^{SOM}$	0.9562
TMG 4185	$93.5944 \times 1.0175^{SOM}$	0.9503
TMG 4182	$97.6315 \times 1.0132^{SOM}$	0.9597
BRSGO 7560	$115.6698 \times 1.0153^{SOM}$	0.8362
FT-Cristalina	$57.3562 \times 1.0176^{SOM}$	0.9370

The use of light is the most important process for the productivity of a crop because it is through photosynthesis that the plant accumulates organic matter in its tissues (Melges et al., 1989). The amount of light perceived by the plants through the photoreceptors affects the growth pattern of the plants, that is, in low light quality the soy plants tend to exhibit high growth in height, in order to increase the interception of this resource, besides emitting a smaller quantity of branches (Board, 2000). Considering that irradiance is one of the most important determinants of plant productivity (Taiz & Zeiger, 2004) growth characteristics are used to infer the degree of tolerance of species to low light availability, since growth may reflect the ability of the species to adapt to the radiation conditions of the environment (Naves et al., 1994).

Artificial shading in bean plants, cultivar Negrito 897, caused prolongation of the vegetative cycle, altered the growth habit, and promoted plant elongation (Lopes et al., 1982). In soybeans, artificial shading reduced the accumulation of dry matter in the plant and its organs, and the dry matter content of the stems reduced appreciably with the reduction of solar radiation, and the reduction of solar radiation increased, among several factors, the lodging of the plants (Melges et al., 1989). Besides this, the shading resulted in the stolonization of the soy plants. In this work, by visual analysis, it was observed that some plants submitted to 50% shading and the majority of the plants grown under 70% shading presented lodging in the V2 development stage.

The morphological changes are caused by the increase in apical dominance, induced by the increase in auxin content and/or the lower availability of photo-assimilates and organic nutrients (Lopes & Lima, 2015). This corroborates the information that the increase in height of shaded plants is caused by greater internode elongation and increased apical dominance (Ryle, 1961, Lopes et al., 1983 and Melges et al. 1989a). The apical dominance may have been due to the decrease in photo-assimilates and the increase in auxin levels (Phillips, 1975), since auxin is synthesized in the stem apex and transported in basipet direction to the tissues located below the apex. Its constant supply in the subapical region of the stem or coleoptile is necessary for the continuous elongation of the stem cells (Taiz & Zeiger, 2004).

The apical dominance phenomenon occurs when the growth of the apical bud inhibits the growth of lateral buds (Taiz & Zeiger, 2004). Furthermore, these authors reported that one of the factors that may be involved in apical dominance is that auxin makes the stem apex a drain for the cytokinin produced in the root. The direct application of cytokinin to the axillary buds stimulates the growth of these buds, and the apex, which is the main source of AIA, maintains high levels of ABA in the lateral buds, inhibiting the growth of lateral buds.

Under field conditions, the density of plants together with the change in spacing between rows, alters the spatial arrangement of plants in the area, which may affect the intra-specific competition and, consequently, the amount of environmental resources (water, light and nutrients) available for each plant (Rambo et al., 2004). The competition between soybean plants, for example, light, may result in alteration in plant growth (Balbinot Júnior et al., 2015). High populations (high plant density per area) can lead, among several factors, to an increase in the possibility of plant lodging (Zito et al., 2007).

Increasing the density of soybean plants causes a reduction in the diameter of the stem in the basis region, the number of nodes on the stems and the number of branches per area (Procópio et al., 2013; Procópio et al., 2014). According to these authors, can be attributed to the decrease in the availability of environmental resources for each individual. Procópio et al. (2013), when studying the increase in density, identified an increase in internode length that occurred due to the reduction in the amount of light resulting from the increase in the number of plants per area. Results similar to those found by Martins et al. (1999) who reported greater intraspecific competition caused by increased plant density, causing plant stretching and favoring the lodging of plants

Rocha et al. (2018) in a study on the cross seeding system in soybean reported that due to the increase in the population of plants in the same area, a greater competition between them will occur, culminating in greater plant height. And, Balbinot Júnior et al. (2015) reported that the height of plants evaluated at 36 and 63 days after sowing was affected by the sowing density, that is, higher sowing density conferred higher plant height, possibly due to the lower amount of light present in the canopy. In a greenhouse, Camargos et al. (2019) reported that the highest epicotyl length averages were obtained in pots containing 3 plants to the detriment of pots containing 1 plant per pot, i.e., greater epicotyl length values were found when seedlings were grown in a greater number of individuals per pot.

CONCLUSIONS

The soybean cultivars differed in epicotyl length, epicotyl diameter and plant height, when evaluated at the V2 development stage.

The shading levels influenced the growth of the analyzed characters, and the increase in the shading level, in the range of 0% to 70%, caused an increase in the epicotyl length and plant height.

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