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Initial Growth of Soybean Plants from Seeds of High and Low Vigor Subjected to Water Stress

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Abstract

This study intends to evaluate responses on the growth of soybeans plants from seeds with high and low vigor in different drought periods. Experimental design was completely randomized in factorial AXB (Factor A: variables 0, 2, 3, 4 and 5 water stress; Factor B: level of seed vigor, high and low). Evaluations of fresh matter, plant height, leaf area and dry weight of shoots, 10, 20, 30 and 40 days after emergence (DAE). Soybean plants originated from seeds with high physiological quality perform better than the plants originated from seeds of low vigor, until 40 DAE. Water stress reduces the initial growth of soybean plants originated from seeds of both high and low force, until 40 DAE. Soybean seeds of high vigor generate plants with higher growth rate of the culture until 30 DAE, besides generating plants with greater capacity for growth after returning water stress.

Keywords: *Glycine max* (L.) Merrill, Early growth, Growth rate, Physiological quality

1. Introduction

Agriculture in Rio Grande do Sul is predominantly characterized by the spring-summer crops, especially soybean and rice, which account for approximately 70% of total grain production in the State. Soybean accounts represent 41% of total grain production of the State, highlighting the fundamental economic and social importance that the grain has (Conab, 2010).

The unpredictability of climatic variation gives the occurrence of adverse weather, the main risk factor of soybean cultivation failures. In a report on agricultural security prepared by the Ministry of Planning (Göpfert et al., 1993), Brazil has the occurrence of drought, as the main problem (71% of cases), followed by excessive rainfall (22% of cases), hail and frost. The frequent droughts in Southern of Brazil are the cause of major crop damage, since the rainfall is the main source of water for crops. The higher frequency of drought occurs in summer, affecting crops of great importance concerning the acreage and production, as soybean, corn and bean.

When the water loss of a tissue is slow but sufficiently to allow changes in development processes, water stress has various effects on growth, one of them is the limitation of leaf expansion (Taiz and Zeiger, 2004). The reduction in water availability in the soil, affects negatively the plant growth and development (Sinclair e Ludlow, 1986). Levit (1980) notes the importance of analyzing the plants responses and their defense mechanisms to soil water deficit. Water stress affect the metabolism negatively, hindering the formation of leaf area, reducing the photosynthetic rate, leading to reduced supply of assimilates and abortion or reduction of developing seeds (Marcos Filho, 2005). This situation does not favor the crop development, affecting seeds production their quality. The effect of water stress in the production depends on the time of occurrence and severity. In soybeans, the stages of germination and emergence, reduces plant stand (Berlato, 1981; Fageria, 1989). However, the use of irrigation can minimize the effects of water stress on seed vigor, as shown by several researchers (Dornbos et al., 1989; Heatherly, 1993; Smiciklas et al., 1989).

The crop success is influenced directly by a high-quality seed which contributes significantly to achieve high yields, while low-quality seeds, has direct influence on the low crop productivity (Krzyzanowski and França Neto, 2003). Seeds vigor has great influence on the establishment of the initial population and plant development, affecting the final result (Hampton, 2002). In addition, more vigorous seeds are more resistant to conditions of less water availability, favoring the establishment of the crop (Tekrony and Egli, 1991). Accordingly, considering the growth of individual plants in populations of soybean plants, (Kolchinski et al., 2005) found that plants from high vigor seeds had higher grain yield. Similar results were found with rice seeds by Melo et al. (2006) and Mielezrski et al. (2008), which showed that plants originated from seeds of high vigor achieve more high yields than those plants originated from low vigor seeds.

Despite the complexity involved in the growth of plant species, growth analysis is an efficient method to monitor the plant progress and measure the contribution of different physiological processes on the plant behavior (Benincasa, 2003). Campos et al. (2008), consider the analysis of growth as an important measure to explain the development of plants, due that about 90% of dry matter accumulation by plants throughout their development, results from photosynthetic activity, allowing evaluate the entire growth of the plant and the contribution of different organs in overall development.

This study intends to evaluate effects of water stress periods on the initial growth of soybeans plants from seeds of high and low vigor.

2. Material and Methods

2.1 Soil and Seed Features

This study was conducted in the season 2009/2010, in a greenhouse at the Laboratório Didático de Análise de Sementes of the Faculdade de Agronomia Eliseu Maciel, Universidade Federal de Pelotas/ RS, Brazil.

Pots with 15 liters of capacity were filled with soil, collected from the A1 horizon of a PLANOSSOLO HÁPLICO Eutrófico Solódico (Embrapa, 2006) according to the mapping unit Pelotas, Brazil. The fertilization was performed according to CFQS RS/SC (Committee of Fertility and Soil Chemistry - RS - SC, 2004). The nutrients were incorporated to the soil five days before sowing and the liming was performed sixty days before sowing.

The cultivar used was M-SOY 8008 RR, which is classified as susceptible cultivar to water stress. Prior to sowing, seeds were treated with inoculant Gelfix 5®, 200 ml/100 kg of seed and fungicide (chemical group Fenilpirrol + Acilalaninato and active ingredient, fludioxinil + Metalaxyl-M (25 gl^{-1} + 10 gl^{-1})), Maxim-XL® at a dosage of 100 ml/100 kg and seed polymer (Sepiret®, blue) at a dosage of 250 ml/100 kg of seed. Plant growths and development is positively influenced by seed treatment, as well as physiologic process. However, emphasizes that all treatments on this work were submitted by the same products.

In Brazil, germination is the standard test to commercialize seeds, which minimum is 80% for soybeans. Then, in this work, were performed germination (G) and vigor (FCG) test to choose high and low vigorbatches. For the selection of seeds lots to be used was evaluated G, performed with four replicates of 50 seeds for each vigor level, placed on a substrate of germination paper ("germitest"), previously soaked in water, using 2.5 times the mass of dry paper, and kept at 25 °C. The evaluations were done according to the RAS -Rules for Testing Seeds (Brazil, 2009) and carried out on the eighth day after sowing. Results were expressed as percentage of normal seedlings. The first count of germination (FCG) was lead together with the germination test and evaluated on the fifth day after sowing. The field emergence test (FE) was carried out in plots containing soil, and the manual seeding depth from 0.02 to 0.03 m, using 400 seeds for each level of vigor (four replicates of 100 seeds). The emergence percentage was obtained by counting emerged seedlings in the twenty-first day after sowing.The physiological quality level of seeds was obtained from seeds lots produced in the growing season of 2008/2009. The high vigor seed showed 88% germination (G), 82% in the first count of germination (FCG) and 87% field emergence (FE), while the low vigor lot showed 75% G, 61% FCG and 74% FE. It was sown 10 seeds per pot to allow further diminishing, removing seedlings earlier in the lot of low vigor and later in the high vigor, with the intention of using the seedlings emerged in the days of major emergency frequency for each level of vigor, leaving at the end, four plants per pot.

2.2 Water Treatment and Assessments

The different water restrictions used, which correspond to the treatments, were applied when 51% of the plants were in the stage VE, according to the scale of Fehr and Caviness (1977). Considering the viable seeds used, it was reached, approximately, five to seven days after sowing, for both high and low vigor seeds.

The treatments consisted of five periods of water deficit and two levels of seed vigor. The periods of water deficits were: control with irrigation (daily irrigation); water deficit from 1 to 10 days after emergence (DAE); water deficit from 11 to 20 DAE; water deficit from 21 to 30 DAE and water deficit from 31 to 40 DAE. Vigor levels studied were high and low, with a total of ten treatments with four replications each. Therefore, before and after periods of water deficit, the experimental units were irrigated daily.

Assessments of the effect of physiological quality combined with the water deficit and initial growth was performed on isolated plants. The following determinations were done: fresh matter (FM), plant height (PH), leaf area (LA) and dry matter (DM). For these determinations, it was collected one plant, cut at ground level at 10, 20, 30 and 40 days after emergence (DAE), remaining three plants, two plants and one plant per pot respectively. For measuring the fresh matter, it used an analytical balance with precision composition. The leaf area of the aerial part of plants was determined using photoelectric determiner (Area Meter, model LI-3100 Li-color Ltda.) giving direct reading in cm^2. To determine the plant height, the measurement was carried out with the aid of rule and the results were expressed in centimeters. The dry matter of shoots was evaluated by a drying at 60 ºC, in which the seedlings were kept for 72 hours drying and weighed on an analytical balance with precision composition after that.

By the results of leaf area and dry weight, it was determined: growth rate of culture - GRC (mg pl^{-1} day^{-1}), relative growth rate - RGR (mg g^{-1} day^{-1}), net assimilation rate - NAR (mg cm^{-2} day^{-1}). These determinations were based on the methodology described in Gardner et al. (1985), in which: GRC = (DM2 - DM1)/(T2 - T1), RGR = (ln DM2 - ln DM1)/(T2 - T1), NAR = (DM2 - DM1)/(T2 - T1) * (LA2 ln - ln LA1)/(LA2 - LA1), where: DM: dry mass, T: time, LA: leaf area.

2.3 Statistical Analysis

The statistical analysis was performed on the Statistical Analysis System for Windows - WinStat - Version 2.0 (Machado and Conceição, 2003). The experimental design was randomized, and the data subjected to analysis of variance and in the presence of significant interaction, proceeded to the developments needed. Means were compared using the Duncan test at 5% probability, in factorial AXB (variables 0, 2, 3, 4 and 5 periods of water deficit and two levels of vigor), with four replications.

3. Results and Discussion

3.1 Evaluation 10 Days after Emergence (DAE)

The results presented in Table 1 show that plants from seeds of high and low vigor do not differ statistically for FF in both water regimes. Variable in AP, shows that plants originated from seeds of high vigor perform better than plants originated from low vigor seeds. Positive effects of physiological seed quality on plant height were also found in other studies, however, as evaluated at different periods of plant development. In soybean, Vanzolini and Carvalho (2002) observed that seeds lots with low physiological quality resulted in plants with lower heights at 18 and 38 days after sowing, compared to lots of medium and high quality. According to the authors, these data probably reflect the rate of emergence of seedlings originated from seeds of low physiological quality that was significantly lower compared to other batches. As Kolchinski et al. (2006), soybean plants originated from seeds of higher physiological quality, showed the highest growth rates in culture, as a result of plants with greater dry weight and leaf area at 30 days after emergence, and similar results were observed by Machado and Schuch (2004) in oat, Hofs et al. (2004) in rice and Schuch et al. (2000) in oats. For the variables FA and FS, it seems that plants grown with seeds from high vigor plants already provide high performance than seeds from low vigor plants. However, plants grown from seeds with high and low vigor when subjected to water deficit from 0 to 10 DAE did not differ significantly. It is possible to be seen in Table 1, according to the variables FF, GG, AF, FS that plants from both seeds with high and low vigor when submitted to drought, have underperformed plants compared to plants without water deficit (Control). The occurrence of severe water deficit in the vegetative stage may compromise the yield due to less development of plants (Mundstock and Thomas, 2005).

3.2 Evaluation 20 Days after Emergence (DAE)

The data presented in Table 2 show that plants grown from seeds with high physiological quality have higher FF and AF in the three water deficit periods studied. Seeds are more vigorous in process capacity of reserves in storage tissues and greater incorporation of their embryonic axis (Dan et al., 1987). This should result in more fast and uniform emergence and seedlings with larger initial size (Vanzolini and Carvalho, 2002) thereby influencing the leaf area and dry matter accumulation. Similar results were found in oats by Schuch et al. (1999) when seedlings from seeds with high vigor, had higher initial size, which consequently led to higher rates of crop growth, dry matter production and leaf area during the initial period of growth. It was also noted that the control treatment showed better performance than the water deficit studied for variables FF and GG. This result is similar to those reported by Hoogenboom et al. (1987) and Thomas and Costa (1994), which water deficit decreases the height of soybean plants. Concerning the FA and FS, it shows that the control treatment differed significantly from other treatments, proving that water deficit caused by 20 DAE reduced the performance of soybean plants from both high and low vigor. The reduction in relative water content of leaves is caused by deficiency of water in the soil since photosynthesis occurs during the loss of water through the stomatal mechanism and the rate of assimilation of water is adversely affected during water stress (Versluis et al., 2006). In relation to seed vigor, there is a difference in plants originated from seeds of high and low vigor, with plants from seeds of high vigor performs better than the plants from seeds of low vigor in the variable AF. However, it was found that for FS seeds of high and low vigor when subjected to water deficit from 11 to 20 DAE did not differ statistically. It was observed that plants suffering water deficit in the period from 10 to 10 DAE, even irrigated thereafter until 20 DAE, did not restore normal growth in those variables when compared with treatments without water deficit (Control).

3.3 Evaluation 30 Days after Emergence (DAE)

From Table 3 presents data from the evaluation at 30 DAE, we considered that plants originated from seeds with high vigor show higher FF and FS, in four water regimes periods studied. There is even no outperforming treatment in other water deficit periods studied. It was observed that plants suffering water deficit from 10 to 10 DAE, after 20 days irrigated daily shown better performance than plants with water deficit from 11 to 20 and 21 to 30 DAE, but are unable to restore usually growth when compared to treatments without water deficit (control). The physiological quality of seeds did not significantly affect the AP with any statistical difference between plants grown from seeds with high and low vigor. The treatment without water deficit (control) showed superior performance to other periods of water deficits. Seeds with low vigor should lead to reductions in field emergence, speed of emergence and initial plant size (Schuch, 2006). Assessing the behavior of individual plants in communities of soybean Kolchinski et al. (2005) found that the effect of physiological seed quality on seedling determined higher seed yields. According to the authors, the use of seeds with high physiological quality provided greater leaf area and dry matter production and, consequently, initial competitive advantage in the exploitation of environmental resources, which resulted in the later stages of development until the maturation phase, resulting at higher seed yield.

The vigor of the seeds positively affected the variable AF up to 30 DAE, which can be seen in Table 3. It was also found that plants from high and low vigor 30 days after being irrigated daily compensate the growth, compared with no water deficit treatment (control). In addition, control treatments and deficit from 1 to 10 DAE showed superior performance to other treatments. When water deficit occurs in the early stages of plant development, soybean recovers better than other cultures (Doss and Thurlow, 1974), since it should tolerate short periods of deficit it has a deep root system and the flowering period relatively long (Mota, 1983). With respect to FS, it seems that the treatments without water deficit differed from other treatments.

Water deficit should alter plant metabolism in different ways. It is observed that in water stress condition, there is an increased synthesis of abscisic acid (ABA) in roots, which is subsequently transported to the shoot via the xylem after rainfall or irrigation (Hartung et al., 2002). For Thomas e Costa (1994), the photosynthetically active leaf area of plants is the most sensitive to water deficit and one of the factors that affect crop yields. It is inferred that because of stomatal closure caused by drought stress, the treatments without water deficit, along with treatment with water deficit from 1 to 10 DAE in both levels of vigor, got the best performance for the variables analyzed (Table 3). The superior performance of the control treatment that occurred under irrigation throughout the same period of conducting experiment, reaching the plants expressing the full potential of growth, demonstrate the negative effects of drought on the parameters. The level of proline, according to Kishor et al., 1995, increased significantly only after 4 days of plants suffer from water deficit, and this accumulation is a characteristic response of plants under abiotic stress, which acts as osmotic regulator in order to reduce the negative effects in plants under adverse conditions. In addition, it promotes increased resistance of cells in these conditions (Xiong and Zhu, 2002). Similar results on the proline accumulation in plants under water deficit were presented by Sarker et al. (1999) working with cultivars of *Triticum aestivum* and Costa (1999) studying *Vigna unguiculata*.

3.4 Evaluation 40 Days after Emergence (DAE)

Regarding the assessment at 40 DAE, Table 4 shows that plants from high vigor seeds were superior to the plants originated from seeds of low vigor, and to the control treatment in four periods with water deficit studied in four variables. This behavior suggests a direct effect of seed vigor on the ability of the tissues of soybean plants to convert solar radiation into dry matter during this period of growth. However, for Tekrony and Egli (1991), the direct effects of seed vigor on the further development of the plants are unlikely to occur. According to these authors, the structures present in the seeds are important for growth only during a short period immediately after emergence. It presumes that most of the plant tissues involved in the production of dry matter and yield are formed after the emergency.

Severe water deficit in the vegetative phase, according to Bonato (2000), should reduce plant growth, leaf area and yield. It also determines the water deficit plants of smaller stature, stunted, with small leaves and short internodes. Results obtained by Petry (2000) confirm that water deficit reduces vegetative growth of soybean due to the decrease in the number of nodes and the length between. If observed in Table 4, it is clear that treatments under periods of water deficit of 11 to 20 and 1 to 10, in the variables FF and GG respectively, performed significantly better than the other treatments. In variable AF, it is observed that the treatments control with water deficit periods from 1 to 10 and 11 to 20 DAE were superior to other treatments. It is inferred that the growth of roots, is a strategy used by plants to capture water in the substrate in water deficit conditions (Lobato et al. 2008), in which growth and development of plants are dependent on cell turgor, so as the water fills the cell and promotes a positive pressure through this mechanism of tissue extension (Kerbauy, 2004).

3.5 Comparison rate between Different Evaluation Periods

By observation of Table 5, it seems that CRG plants originated from seeds of high vigor had improved performance over plants from low vigor in the periods 1 to 10, 11 to 20 and 21 to 30 DAE. However in the period from 31 to 40 DAE, there was no statistical difference in the growth of plants from seeds of high and low vigor. Oat seeds of high vigor, as Schuch (1999) produced plants with greater dry matter production, leaf area and growth rates in the early period of culture. The control treatment differed significantly from other treatments in periods 1 to 10 and 11 to 20 DAE. In the period from 21 to 30 DAE the water deficit from 1 to 10 DAE results were higher than others. Even during the period from 31 to 40 DAE was observed that water deficit from 11 to 20 DAE was statistically different from other drought periods. It is possible verify that plants grown from seeds with high and low vigor were not affected in the periods 11 to 20, 21 to 30 and 31 to 40 DAE as the RGR, it can also be observed that the treatment with water deficit from 1 to 10 DAE was significantly higher in periods of 11 to 20 and 21 to 30 DAE. However it seems that the period of water deficit from 11 to 20 DAE had superior performance to other periods of drought. Regarding the RAN, there was no statistical difference between plants originating from seeds with high and low vigor during the periods 11 to 20, 21 to 30 and 31 to 40 DAE. The RAN in the period from 11 to 20 DAE showed no significant difference between control and drought treatments from 1 to 10 DAE, as the period from 21 to 30 DAE superior performances in dealing with water deficit from 10 to 1 DAE. In the period from 31 to 40 DAE was observed that the water deficit period from 11 to 20 DAE was statistically higher than other treatments.

4. Conclusion

Soybean plants originated from seeds with high physiological quality performs better than the plants originated from seeds of low vigor, until 40 DAE.

Water stress reduces the initial growth of soybean plants originated from seeds of both high and low vigor until 40 DAE.

Soybean seeds of high vigor produce plants with higher growth rate of the culture until 30 DAE, besides plants with greater capacity for growth after returning water stress.

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Table 1. Fresh mass (FM), plant height (PH), leaf area (LA) and dry mass (DM) of soybean plants originated from seeds with high and low vigor, submitted to water deficit, 10 DAE. Capão do Leão – RS, Brazil, 2010.

Variable	Water stress/Stage***	Vigor		Means
		High	Low	
FM ($g.pl^{-1}$)	Control/VE-V2	3.39	2.77	3.08 a
	1 to 10DAE*/VE-V1	1.53	1.35	1.44 b
	Means	2.46 A**	2.06 A	
	C.V. (%)	16.11		
PH (cm)	Control/VE-V2	14.7	11.1	12.9 a
	1 to10DAE*/VE-V1	10.9	10.6	10.7 b
	Means	12.8 A	10.8 B	
	C.V (%)	12.48		
LA (cm^2 pl^{-1})	Control/VE-V2	95.61 aA	75.92 aB	85.77
	1 to 10DAE*/VE-V1	44.51 b A	41.94 b A	43.23
	Means	70.06	58.93	
	C.V. (%)	10.67		
DM ($g.pl^{-1}$)	Control/VE-V2	0.24 aA	0.18 a B	0.21
	1 to 10DAE*/VE-V1	0.08 b A	0.06 b A	0.07
	Means	0.16	0.12	
	C.V. (%)	15.61		

* DAE: days after emergence, ** Means followed by the same lowercase letter in the column (Water stress) and capital on the line (Vigor) do not differ by Duncan test at 5% of probability. *** phenological stage, according to the scale of Fehr e Caviness (1977).

Table 2. Fresh mass (FM), plant height (PH), leaf area (LA) and dry mass (DM) of soybean plants originated from seeds with high and low vigor, submitted to water deficit, 20 DAE. Capão do Leão - RS, Brazil, 2010

Variable	**Water stress/Stage *****	**Vigor**		**Means**
		High	**Low**	
FM ($g.pl^{-1}$)	Control/VE-V5	14.24	11.68	12.96 a
	1 to 10DAE*/VE-V1	8.14	5.99	7.06 b
	11 to 20DAE/V1 and V3 and V4	5.22	3.85	4.53 c
	Means	9.20 A**	7.17 B	
	C.V. (%)	12.62		
PH (cm)	Control/VE-V5	35.9	34.6	35.2 a
	1 to 10DAE*/VE-V1	28.5	27.8	28.1 b
	11 to 20DAE/V1 and V3 and V4	23.7	23.1	23.4 c
	Means	29.4 A	28.5 A	
	C.V. (%)	11.48		
LA (cm^2 pl^{-1})	Control/VE-V5	490.50 aA	318.77 a B	404.64
	1 to 10DAE*/VE-V1	261.13 b A	176.44 b B	218.79
	11 to 20DAE/V1 and V3 and V4	229.57 b A	153.27 b B	191.42
	Means	327.06	216.16	
	C.V. (%)	10.6		
DM ($g.pl^{-1}$)	Control/VE-V5	2.70 aA	1.69 a B	2.2
	1 to 10DAE*/VE-V1	1.26 b A	0.85 b B	1.06
	11 to 20DAE/V1 and V3 and V4	0.97 b A	0.86 b A	0.92
	Means	1.64	1.13	
	C.V. (%)	16.3		

* DAE: days after emergence, ** Means followed by the same lowercase letter in the column (Water stress) and capital on the line (Vigor) do not differ by Duncan test at 5% of probability; *** phenological stage, according to the scale of Fehr e Caviness (1977).

Table 3. Fresh mass (FM), plant height (PH), leaf area (LA) and dry mass (DM) of soybean plants originated from seeds with high and low vigor, submitted to water deficit, 30 DAE. Capão do Leão - RS, Brazil, 2010

Variable	Water stress/Stage ***	Vigor		Means
		High	Low	
FM ($g.pl^{-1}$)	Control/VE-V7 and V8	25.09	19.76	22.42 a
	1 to 10DAE*/VE and V1	20.63	16.32	18.48 b
	11 to 20DAE/V1 and V3 and V4	15.2	12.37	13.78 c
	21 to 30DAE/V3 and V4-V6 and V7	13.46	11.3	12.38 c
	Means	18.59 A**	14.94 B	
	C.V. (%)	11.8		
PH (cm)	Control/VE-V7 and V8	48.8	47.9	48.4 a
	1 to 10DAE*/VE and V1	45.1	40.4	42.7 b
	11 to 20DAE/V1 and V3 and V4	43.8	43	43.4 b
	21 to 30DAE/V3 and V4-V6 and V7	41.9	40.8	41.4 b
	Means	44.9 A	43.0 A	
	C.V. (%)	9.11		
LA ($cm^2\ pl^{-1}$)	Control/VE-V7 and V8	900.07 aA	631.06 a B	765.56
	1 to 10DAE*/VE and V1	885.96 aA	624.79 a B	755.38
	11 to 20DAE/V1 and V3 and V4	441.37 c A	359.25 b B	400.31
	21 to 30DAE/V3 and V4-V6 and V7	569.73 b A	417.05 b B	493.39
	Means	699.29	508.04	
	C.V. (%)	7.98		
DM ($g.pl^{-1}$)	Control/VE-V7 and V8	5.05	4.02	4.53 a
	1 to 10DAE*/VE and V1	4.54	3.59	4.07 b
	11 to 20DAE/V1 and V3 and V4	2.91	2.11	2.51 c
	21 to 30DAE/V3 and V4-V6 and V7	3.39	2.35	2.87 c
	Means	3.98 A	3.02 B	
	C.V. (%)	12.83		

* DAE: days after emergence, ** Means followed by the same lowercase letter in the column (Water stress) and capital on the line (Vigor) do not differ by Duncan test at 5% of probability; *** phenological stage, according to the scale of Fehr e Caviness (1977).

Table 4. Fresh mass (MF), plant height (PH), leaf area (LA) and dry mass (DM) of soybean plants originated from seeds with high and low vigor, submitted to water deficit, 40 DAE. Capão do Leão - RS, Brazil, 2010

Variable	Water stress/Stage***	Vigor		Means
		High	Low	
MF ($g.pl^{-1}$)	Control/VE-V9	31.36	23.09	27.23 ab
	1 to 10DAE*/VE-V1	29.04	24.01	26.52 ab
	11 to 20DAE/V1 and V3 and V4	28.75	27.75	28.25 a
	21 to 30DAE/V3 and V4 –V6 and V7	25.11	22.18	23.64 b
	31 to 40DAE/V6 and V7 and V8	27.26	21.39	24.32 ab
	Means	28.30 A**	23.69 B	
	C.V. (%)	15.14		
PH (cm)	Control/VE-V9	49.7	44	46.8 ab
	1 to 10DAE*/VE-V1	49	46.4	47.7 a
	11 to 20DAE/V1 and V3 and V4	47.2	42.3	44.7 abc
	21 to 30DAE/V3 and V4 –V6 and V7	47	39.3	43.1 c
	31 to 40DAE/V6 and V7 and V8	47.4	40	43.7 bc
	Means	48.1 A	42.4 B	
	C.V. (%)	6.82		
LA ($cm^2\ pl^{-1}$)	Control/VE-V9	927.81	744.3	836.06 a
	1 to 10DAE*/VE-V1	901.95	721.32	811.63 a
	11 to 20DAE/V1 and V3 and V4	889.34	690.87	790.11 a
	21 to 30DAE/V3 and V4 –V6 and V7	771.61	576.8	674.20 b
	31 to 40DAE/V6 and V7 and V8	769.72	615.55	692.63 b
	Means	852.09 A	669.77 B	
	C.V. (%)	7.33		
DM ($g.pl^{-1}$)	Control/VE-V9	7.54	5.85	6.70 a
	1 to 10DAE*/VE-V1	6.4	4.93	5.69 b
	11 to 20DAE/V1 and V3 and V4	6.62	5.5	6.06 b
	21 to 30DAE/V3 and V4 –V6 and V7	6.13	4.71	5.42 b
	31 to 40DAE/V6 and V7 and V8	8.18	6.17	7.18 a
	Means	6.97 A	5.43 B	
	C.V. (%)	9.93		

* DAE: days after emergence, ** Means followed by the same lowercase letter in the column (Water stress) and capital on the line (Vigor) do not differ by Duncan test at 5% of probability; *** phenological stage, according to the scale of Fehr e Caviness (1977).

Table 5. Growth rate of culture (CRG), relative growth rate (RGR) and net assimilation rate (RAN) of soybean plants from seeds of high and low vigor, submitted to water deficit. Capão do Leão, RS, Brazil, 2010

Period (DAE**)	Water stress	Vigor		Means
		High	Low	
		CRG (mg pl. dia-1)		
1 to 10	Control	24 aA	18 a B	21
	1 to 10 DAE	8 b A	6 b A	7
Means		16	12	
C.V. (%)		14.48		
11 to 20	Control	245	151	198 a
	1 to 10 DAE	117	79	98 b
Means		181 A	115 B	
C.V. (%)		17.42		
21 to 30	Control	235	232	233 b
	1 to 10 DAE	328	273	301 a
	11 to 20 DAE	193	125	159 c
Means		252 A	210 B	
C.V. (%)		21.08		
31 to 40	Control	2486	1835	2161 bc
	1 to 10 DAE	1855	1341	1598 c
	11 to 20 DAE	3709	3387	3548 a
	21 to 30 DAE	2737	2367	2552 b
Means		2697 A	2232 A	
C.V. (%)		31.66		
		RGR (mg g^{-1}. dia^{-1})		
11 to 20	Control	0.023	0.022	0.023 b
	1 to 10 DAE	0.027	0.025	0.026 a
Means		0.025 A	0.023 A	
C.V. (%)		7.97		
21 to 30	Control	0.062	0.086	0.074 c
	1 to 10 DAE	0.128	0.143	0.136 a
	11 to 20 DAE	0.109	0.09	0.099 b
Means		0.100 A	0.107 A	
C.V. (%)		17.7		
31 to 40	Control	0.04	0.037	0.039 c
	1 to 10 DAE	0.034	0.031	0.032 c
	11 to 20 DAE	0.082	0.095	0.089 a
	21 to 30 DAE	0.059	0.07	0.064 b
Means		0.054 A	0.058 A	
C.V. (%)		28.83		
		RAN (mg cm^{-2}. dia^{-1})		
11 to 20	Control	1.02	0.9	0.96 a
	1 to 10 DAE	9.95	0.85	0.92 a
Means		1.01 A	0.87 A	
C.V. (%)		20.54		
21 to 30	Control	0.35	0.51	0.43 c
	1 to 10 DAE	0.65	0.77	0.71 a
	11 to 20 DAE	0.61	0.52	0.56 b
Means		0.53 A	0.60 A	
C.V. (%)		20.46		
31 to 40	Control	0.27	0.27	0.27 c
	1 to 10 DAE	0.21	0.2	0.20 c
	11 to 20 DAE	0.58	0.67	0.62 a
	21 to 30 DAE	0.42	0.49	0.45 b
Means		0.37 A	0.41 A	
C.V. (%)		29.68		

* DAE: days after emergence, ** Means followed by the same lowercase letter in the column (Water stress) and capital on the line (Vigor) do not differ by Duncan test at 5% of probability.