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GERMINATION PERFORMANCE OF GRAIN SORGHUM HYBRID SEEDS TREATED WITH BIOREGULATOR UNDER WATER DEFICIT

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ABSTRACT - Water stress can reduce seed germination speed and percentage, harming the development of seedlings. Thus, it is necessary to find alternatives that can mitigate these effects. Bioregulators have been intensively used in agricultural production and can provide increase in plant growth and development. Therefore, the aim of this work was to evaluate the germination performance of seeds of two grain sorghum hybrids under simulated water deficit treated with bioregulator. The experimental design was completely randomized in a 2 x 4 factorial scheme, with the following factors: two seed treatments (with and without bioregulator) and four osmotic potentials (0; -0.4; -0.8 and -1.2 MPa), with four replicates, separately for the following grain sorghum hybrids: 1G100 and 1G233. Germination, first germination count, shoot and root length and shoot and root dry matter were evaluated. Data obtained were submitted to analysis of variance and means were compared by the Tukey test at 5% probability and regression analysis. The reduction of the osmotic potential to the level of -1.2 MPa reduced the physiological quality of seeds; however, bioregulator application did not result in better seed quality under water stress. Bioregulator Stimulate® increased root length and shoot dry matter of seedlings of grain sorghum cultivar 1G233 in the absence of water deficit.
Keywords: *Sorghum bicolor* (L.) Moench, phytoregulator, water stress.

DESEMPENHO GERMINATIVO DE SEMENTES DE HÍBRIDOS DE SORGO GRANÍFERO TRATADAS COM BIORREGULADOR SOB DEFICIÊNCIA HÍDRICA

RESUMO - O estresse hídrico pode reduzir a velocidade e a porcentagem de germinação das sementes, prejudicando o desenvolvimento das plântulas. Desse modo, é necessário encontrar alternativas que consigam mitigar estes efeitos. Os biorreguladores vêm sendo utilizados intensamente na produção agrícola e podem proporcionar um aumento no crescimento e desenvolvimento das plantas. Diante disso, o objetivo do trabalho foi avaliar o desempenho germinativo de sementes de dois híbridos de sorgo granífero, sob deficiência hídrica simulada, tratadas com biorregulador. O delineamento experimental foi inteiramente casualizado, em esquema fatorial 2 x 4, constituindo-se como fatores: dois tratamentos de sementes (com e sem biorregulador) e quatro potenciais osmóticos (0; -0,4; -0,8 e -1,2 MPa), com quatro repetições, separadamente para os híbridos simples de sorgo granífero: 1G100 e 1G233. Foram avaliadas a germinação, a primeira contagem da germinação, comprimento de parte aérea e raiz e massa da matéria seca de parte aérea e raiz. Os dados obtidos foram submetidos à análise de variância e as médias comparadas pelo teste de Tukey, a 5% de probabilidade e análise de regressão. A redução do potencial osmótico até o nível de -1,2 MPa reduziu a qualidade fisiológica das sementes; entretanto a aplicação de biorregulador não resultou em melhor qualidade das sementes diante do estresse hídrico. O biorregulador Stimulate® elevou o comprimento da raiz e a massa seca de parte aérea das plântulas de sorgo granífero cultivar 1G233, na ausência de déficit hídrico.
Palavras-chave: *Sorghum bicolor* (L.) Moench, fitorregulador, estresse hídrico.

INTRODUCTION

Sorghum (*Sorghum bicolor* (L.) Moench) is considered the fifth most produced cereal in the world, with production of 62.05 million tons in an area of 40.7 million hectares in the 2020/2021 harvest (USDA, 2021). Brazilian production accounted for 4.3% of the total world production, with 2.63 million tons, with the Midwestern and Southern regions accounting for 87.5% of national production (CONAB, 2021).

Grain sorghum represents an interesting choice for use in animal feed in Brazil, especially in regions with low water availability, since the crop has characteristics of relative tolerance to drought and high temperatures (ALBUQUERQUE et al., 2011; SILVA et al., 2015; OLIVEIRA et al., 2020). In addition, this grass is also used for other purposes, such as human feed, a segment that has been growing mainly due to the grain characteristics such as absence of gluten, neutral flavor and high antioxidant capacity (QUEIROZ et al., 2014; HONG et al., 2020; PUNIA et al., 2021). With the growing demand for this cereal in recent years, companies supplying sorghum seeds have developed new grain cultivars, which have differences

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between each other in the vegetative cycle and in other agronomic characteristics, aiming to achieve greater grain yield (SILVA et al., 2009).

To achieve high yields, it is necessary to use high quality seeds, which provide higher emergence speed and adequate stand establishment in the field (ABATI et al., 2017; BAGATELI et al., 2020; 2022; EBONE et al., 2020). According to França-Neto et al. (2016), the seed must have genetic, physical, physiological and sanitary properties, which guarantees good agronomic performance, which is essential for optimal crop performance. Several internal and external factors influence seed germination. Internal factors are inherent to the seed, such as longevity and viability; external factors are related to environmental conditions, especially temperature, water availability and oxygen, and if one of these three conditions is not satisfactory, seed does not germinate (MARCOS-FILHO, 2015).

Water uptake is essential for the resumption of the seed's metabolic activities after maturity, and germination occurs when seeds reach adequate hydration level. It is noteworthy that both water excess and deficit can cause irreversible damage (MARCOS-FILHO, 2015; OBROUCHEVA et al., 2017). Water deficit generates complex processes, reducing seed germination speed and the formation of normal seedlings. For each species, there is a limit water potential level in the soil, below which germination does not occur (LOPES; MACEDO, 2008). It is noteworthy that situations of low water availability are often observed in crops; therefore, there is a need to understand the germination behavior of species and cultivars in the face of such situations, as well as to seek alternatives that can minimize the effects of low water availability.

The use of new products and improved seeds combined with proper management are measures to increase crop productivity. The use of bioregulators is highly relevant, as they are natural or synthetic compounds that can be used in seeds, plants and soil and cause changes in vital and structural processes with the aim of optimizing crop productivity and quality (ÁVILA et al., 2008).

Bioregulators help overcoming abiotic stresses, as they act as hormonal and nutritional increment. The use of growth regulators in seed treatment and at early stages of seedling development can provide root growth, accelerating the recovery of seedlings in adverse situations such as water stress (LANA et al., 2009). Favorable results were found in the application of these substances by Binsfeld et al. (2014), who observed that the treatment of soybean seeds with bioregulator had a positive influence on the initial seedling performance, showing greater root growth and seedling dry mass. Barbieri et al. (2014) found that the treatment of maize seeds with bioregulator caused an increase in the formation of normal seedlings, higher germination speed and more accentuated development of the root system.

Given the above, the aim of this work was to evaluate the germination performance of seeds of two grain sorghum hybrids under simulated water deficit and treated with bioregulators (indolbutyric acid, kinetin and gibberellic acid).

MATERIAL AND METHODS

The experiment was carried out at the Laboratory of Phytotechnics, State University of Londrina (UEL), Londrina, Paraná, Brazil. The experimental design used was completely randomized, in a 2 x 4 factorial scheme [2 seed treatments (with and without bioregulator) x 4 osmotic potentials (0.0; -0.4; -0.8 and -1.2 MPa)], with four replicates. Seeds of two grain sorghum hybrids were used: 1G100 and 1G233, evaluated separately.

The bioregulator used for seed treatment was the commercial product Stimulate®, at dose of 1 L 100 kg^{-1} of seeds, consisting of 0.005% indolebutyric acid (auxin), 0.009% kinetin (cytokinin) and 0.005% gibberellic acid (gibberellin) (STOLLER DO BRASIL, 1998). To simulate water deficit, the germitest papers used as substrate for carrying out the physiological quality tests of seeds were moistened with distilled water in the amount of 2.5 times the substrate mass and with polyethylene glycol solutions (PEG 6000), providing osmotic potentials of 0.0 (distilled water); -0.4; -0.8 and -1.2 MPa. PEG 6000 concentrations used to obtain each treatment are shown in Table 1 (VILLELA et al., 1991).

TABLE 1 - Polyethylene glycol (PEG 6000) concentrations (g L^{-1}) used to obtain the osmotic potentials at temperature of 25ºC.

Estimated osmotic potential (MPa)	Concentrations (g PEG 6000 L^{-1} distilled water)
0.0	0
-0.4	178.343
-0.8	261.948
-1.2	326.261

The physiological quality of seeds was evaluated through germination tests, first germination count, shoot length, root length, shoot dry matter and root dry matter, according to methodologies described below.

Germination: carried out with two subsamples of 50 seeds per replicate, totaling 400 seeds per treatment. Seeds were distributed on the germitest paper moistened with pre-established solutions (Table 1). Seeds were conditioned in the form of rolls in germinator at temperature of 25ºC, for ten days. Subsequently, evaluations were carried out according to recommendations of the Rules for Seed Analysis (BRASIL, 2009), and results were expressed in percentage of normal seedlings.

First germination count: performed together with the germination test. Evaluation was carried out after four days of sowing, counting only normal seedlings (BRASIL, 2009).

Shoot length and root length: two subsamples of 25 seeds per replicate were used. Seeds were arranged in the upper third in the longitudinal direction of the paper. Rolls were placed in plastic bags vertically positioned in germinator set at 25ºC for seven days. Subsequently, normal seedlings were measured (shoot and root length) with the aid of a millimeter ruler. Results were expressed in centimeters (KRZYZANOWSKI et al., 2020).

Shoot and root dry matter: performed with normal seedlings obtained in the seedling length test. After measuring seedling length, the rest of the seed was removed and shoots were separated from roots. Then, they were placed in paper bag and taken to an oven with forced air circulation, remaining for 24 h at temperature of 80ºC (KRZYZANOWSKI et al., 2020). At the end of this period, dry mass was evaluated on scale with precision of 0.0001 g, and results were expressed in mg per seedling.

Data obtained were submitted to analysis of variance and means were compared by the Tukey test, at 5% error probability. Quantitative data were submitted to regression analysis up to the 2nd degree. Analyses were performed using the Sisvar software (FERREIRA, 2011).

RESULTS AND DISCUSSION

The summary of the analysis of variance (Table 2) indicates that for cultivar 1G100, all variables had an isolated effect for the osmotic potential, and the interaction between bioregulator and osmotic potential was only observed for shoot length. Seed germination decreased linearly as the osmotic potential decreased, with decrease of 81% when osmotic potential of 0 MPa was compared with osmotic potential of -1.2 MPa (Figure 1). In Figure 1, it is possible to verify for all variables that evaluate seed vigor (first germination count, shoot length, root length, shoot dry matter and root dry matter), that they adjusted to linear equations, that is, they were impaired by the reduction in the osmotic potential (Figure 1), while bioregulator application did not improve seed germination and vigor in any of the tests performed (Table 2).

However, instead of benefiting seedling development, the bioregulator used reduced shoot length of seedlings of this cultivar in the absence of water deficit, while in the other osmotic potentials, its effect was not significant (Table 3). Buchelt et al. (2019) also observed that the bioregulator (Stimulate®) application did not influence germination and shoot fresh mass and root dry matter in the maize crop.

TABLE 2 - Summary of the analysis of variance for the physiological quality characteristics of grain sorghum seeds (cultivars 1G100 and 1G233), as a function of treatment with and without bioregulator and osmotic potentials (0.0; -0.4; -0.8 and -1.2 MPa).

		Mean squares					
		1G100					
Variation factor	GL	G (%)	FGC (%)	SL (cm)	RL (cm)	SDM (mg)	RDM (mg)
Bioregulator (Bio.)	1	112.50^{ns}	32.00^{ns}	0.07^{ns}	19.84^{ns}	0.43^{ns}	0.290^{ns}
Osmotic Potential (PO)	3	11734.54*	14996.25*	303.77*	402.77*	191.78*	15.88*
Bio. x PO	3	66.75^{ns}	42.58^{ns}	1.76*	3.15^{ns}	0.52^{ns}	0.177^{ns}
Error	24	35.39	16.70	0.58	5.69	0.59	0.228
Mean		58.06	41.62	5.02	7.50	4.10	1.42
CV(%)		10.25	9.82	15.24	31.82	18.76	33.48
		1G233					
Bioregulator (Bio.)	1	144.50*	318.78*	0.18^{ns}	3.00*	0.000078*	0.0258^{ns}
Osmotic Potential (PO)	3	10388.79*	11241.86*	408.06*	501.31*	222.83*	16.66*
Bio. x PO	3	97.50*	279.94*	0.46^{ns}	4.96*	0.866*	0.152^{ns}
Error	24	23.89	28.95	0.25	0.27	0.21	0.11
Mean		45.68	31.96	5.02	6.73	3.69	1.12
CV(%)		10.7	16.83	10.11	7.80	12.50	29.23

ns = not significant and *= significant at 5% probability, by the F test. GL = degrees of freedom, G = germination, FGC = first germination count, SL = shoot length, RL = root length, SDM = shoot dry matter and RDM = root dry matter.

Results verified by Cazarim et al. (2021) corroborate those observed in this work regarding the reduction of the physiological quality of seeds due to the different water potentials. These authors, studying the effect of simulated water deficit conditions (0; -0.2; -0.4 and -0.6 MPa), observed that the more negative the water potential, the greater the reduction in millet seed and seedling performance. The decrease in the physiological quality of seeds submitted to water stress can be attributed to the reduction of water absorbed by seeds, which can trigger inhibition of the synthesis and/or activity of hydrolytic enzymes essential for germination (AZERÊDO et al., 2016), due to the increase in the concentration of osmotic solutions. In addition, the reduction in water uptake by seeds generally influences germination capacity and seedling development, considering that water deficit is one of the limiting factors for seed germination, since water triggers this process and is involved, directly or indirectly, in all subsequent stages of seedling and plant metabolism (RAJJOU et al., 2012; MARCOS-FILHO, 2015).

In the present study, seedling length was negatively affected by the reduction in the osmotic potential (Figures 1 and 2), since water is the most essential factor for germination and its uptake is necessary to generate turgor pressure that enhances cell expansion, which is the basis of vegetative growth and development (TAIZ et al., 2017).

Similar results were observed by Girotto et al. (2012). The authors found decreases in shoot and root length of seedlings of wheat genotypes submitted to water stress induced by mannitol and PEG 6000.

Cultivar 1G233 showed significant interaction between osmotic potential and bioregulator application for all variables, except for shoot length and root dry matter, which were only influenced by the osmotic potential (Table 2).

The applied bioregulator dose did not result in better germination and first germination count percentages of sorghum seeds of hybrid 1G233 (Table 3). The results obtained in the present study are compatible with those obtained by Ferreira et al. (2007) and Silva et al. (2008) in maize, which did not improve germination due to the application of Stimulate® at doses of 1.25 and 1.5 L 100 kg^{-1} of seeds, respectively. Santos et al. (2013) found that the use of Stimulate® increased germination and the seedling emergence percentage; however, the authors studied the effect of the bioregulator on the sunflower crop and the treatment was carried out via pre-imbibition of seeds, which demonstrates that the action of this product may vary according to the form of application and species. In Table 3, it is possible to verify that at the osmotic potential of -0.8 MPa, the number of normal seedlings of hybrid 1G233 reduced in the order of 14 percentage points when using the bioregulator in relation to seeds not treated with the bioregulator.

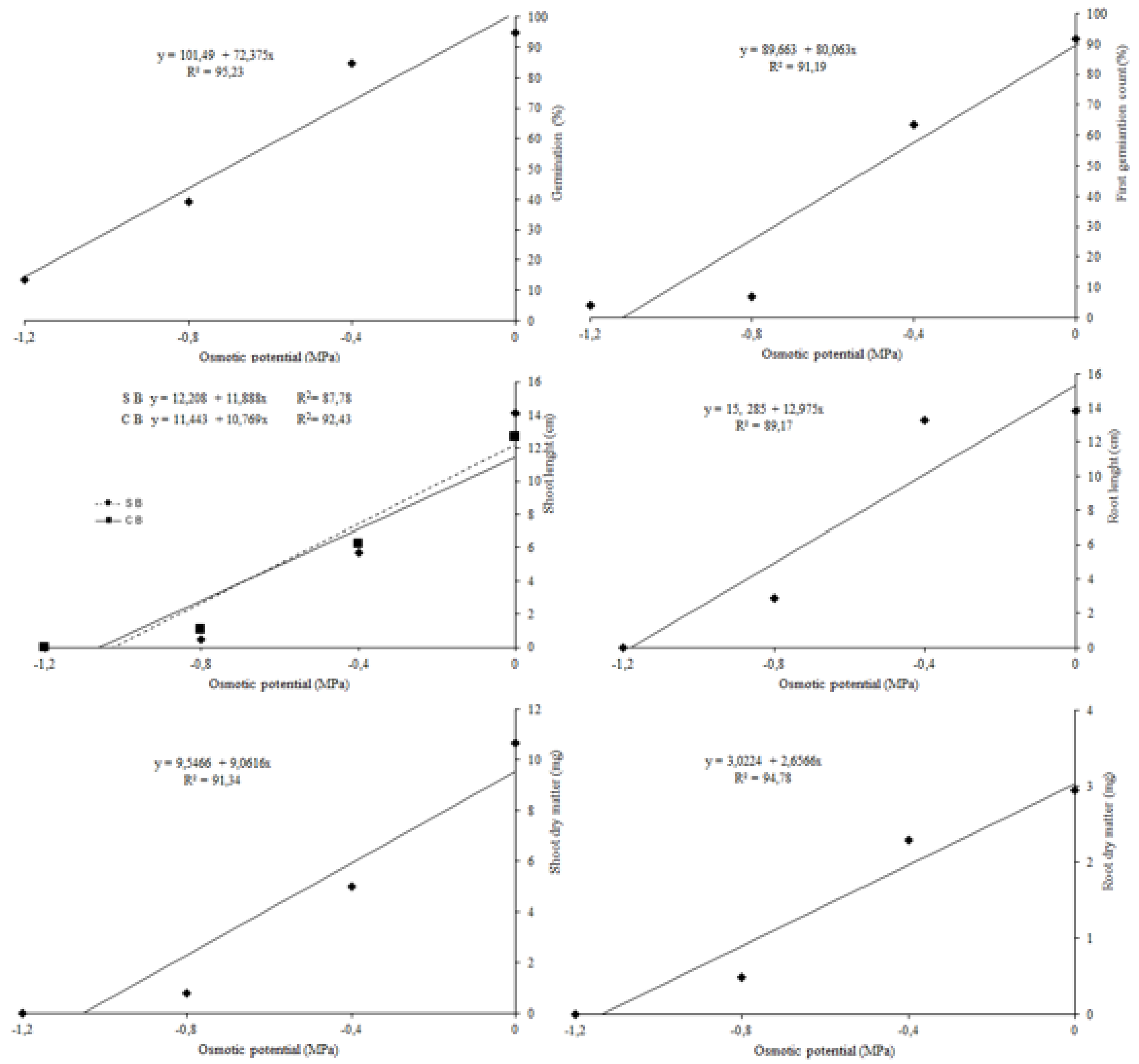

FIGURE 1 - Germination (%), first germination count (%), shoot length (cm), root length (cm), shoot dry matter (mg) and root dry matter (mg), of seeds of grain sorghum cultivar 1G100, without bioregulator (SB) and with bioregulator (CB) and submitted to osmotic potentials.

Root length and shoot dry matter of cultivar 1G233 were benefited by bioregulator application in the absence of water deficit (0.0 MPa), with increases in these variables of 21.35% and 7.41 %, respectively, due to the use of the bioregulator (Table 3), compared to the absence of bioregulator. Thus, under adequate water availability conditions, the bioregulator possibly altered seed metabolism, which may have resulted in greater efficiency in the mobilization and transfer of dry matter from seed reserve tissues to the embryonic axis, thus influencing growth and biomass accumulation in the shoots of sorghum seedlings.

In the other osmotic potentials (-0.4; -0.8 and -1.2 MPa), the bioregulator had no significant effect on these variables (Table 3). Dario and Baltieri (1998) studied the application of the same bioregulator in maize and also obtained increase in the dry biomass of seedlings in relation to control 6 days after sowing, with application to seeds at dose of 2.5 L 100 kg $^{-1}$ of seeds. This increase in the dry mass of seedlings suggests a possible accumulation of carbohydrates that could be transformed into higher productive yields. Pereira et al. (2021) found that the use of bioregulator (Stimulate®) via seed treatment together with the use of polymer and drying powder favored the total length of soybean seedlings in relation to the control condition (without seed treatment).

TABLE 3 - Shoot length (cm), germination (%), first germination count (%), root length (cm) and shoot dry matter (mg) of seeds of two sorghum hybrids, with/without bioregulator, in osmotic potentials.

	Osmotic potentials (Mpa)			
	0.0	-0.4	-0.8	-1.2
	Cultivar 1G100			
	Shoot length (cm)			
Without bioregulator	14.10 a*	5.72 a	0.47 a	0.00 a
With bioregulator	12.65 b	6.20 a	1.07 a	0.00 a
CV(%)	15.24			
	Cultivar 1G233			
	Germination (%)			
Without bioregulator	78 a	76 a	38 a	0 a
With bioregulator	77 a	71 a	24 b	3 a
CV(%)	10.70			
	First germination count (%)			
Without bioregulator	76 a	62 a	3 a	0 a
With bioregulator	76 a	38 a	1 a	0 a
CV(%)	16.83			
	Root length (cm)			
Without bioregulator	13.82 b	11.87 a	0.00 a	0.00 a
With bioregulator	16.77 a	11.37 a	0.00 a	0.00 a
CV(%)	7.80			
	Shoot dry matter (mg)			
Without bioregulator	10.79 b	4.00 a	0.00 a	0.00 a
With bioregulator	11.59 a	3.19 b	0.00 a	0.00 a
CV(%)	12.50			

*Means followed by the same letter in the column do not differ by the Tukey's test, at 5% error probability.

Linear regression models reveal that all variables for sorghum cultivar 1G233 were harmed by the reduction in osmotic potential as expected, which was also observed for cultivar 1G100, although the rate of decrease in variables that showed interaction was different as a function of the bioregulator application (Figure 2).

Although the linear regression for variables root length and shoot dry matter for cultivar 1G233 indicates a gain obtained by the bioregulator application, data obtained in this study show that the bioregulator application, in general, was not efficient in increasing the physiological quality of sorghum seeds, even when submitted to stress conditions. In this sense, Carvalho et al. (2020) studied the effect of bioregulators on the performance of grain sorghum and found no significant differences for the first germination count, germination, fresh biomass and germination speed index between control treatment and treatment with Stimulate®.

The results of this study indicate that bioregulator application in grain sorghum seeds can favor the increase in shoot dry matter and seedling root length in the absence of water deficit. However, bioregulator application did not increase the phytometric variables of grain sorghum under water stress conditions. Thus, further studies should be carried out to find ways to mitigate the effects of water stress on grain sorghum seeds, aiming at obtaining greater establishment of plants with higher seedling quality in the field.

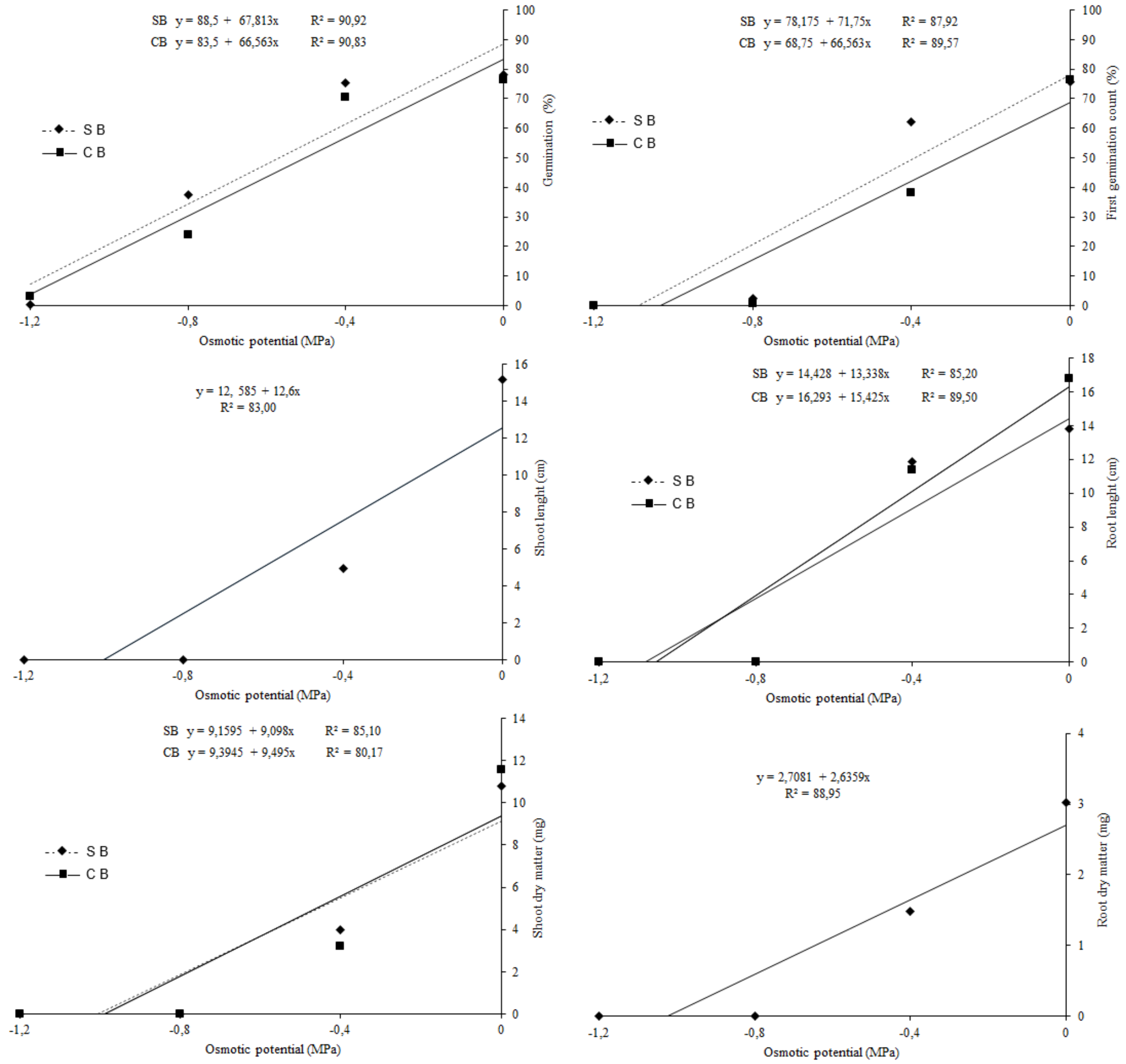

FIGURE 2 - Germination (%), first germination count (%), shoot length (cm), root length (cm), shoot dry matter (mg) and root dry matter (mg), of seeds of grain sorghum cultivar 1G233, without bioregulator (SB) and with bioregulator (CB), submitted to osmotic potentials.

CONCLUSIONS

The reduction in the osmotic potential to the level of -1.2 MPa reduced the physiological quality of seeds; however, bioregulator application did not result in better seed quality under water stress.

Bioregulator Stimulate® increased root length and shoot dry matter of seedlings of grain sorghum cultivar 1G233 in the absence of water deficit.

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