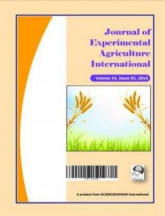

Journal of Experimental Agriculture International

26(4): 1-11, 2018; Article no.JEAI.41876
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Biostimulant Doses X Stress Conditions on the Germination and Seedling Characteristics of Sunflower Seeds

Carla Michelle da Silva[1], Elizeth Regina Raisse[1], Antônio Veimar da Silva[2*] and Eduardo Fontes Araújo[3]

[1]Department of Agronomy and Plant Science, Universidade Federal de Viçosa – Campus Universitário, Viçosa – MG, Brasil.
[2]Department of Plant Protection, Universidade Federal de Viçosa – Campus Universitário, Viçosa – MG, Brasil.
[3]Universidade Federal de Viçosa – Campus Universitário, Viçosa – MG, Brasil.

Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2018/41876
Editor(s):
(1) Dr. Mohammad Reza Naroui Rad, Department of Seed and Plant improvement, Sistan Agricultural and Natural Resources Research Center, AREEO, Zabol, Iran.
Reviewers:
(1) Guillermo Castañón Nájera, Universidad Juárez Autónoma de Tabasco, México.
(2) Aydın Ünay, Adnan Menderes University Aydin, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/26504

Original Research Article

Received 02 May 2018
Accepted 14 September 2018
Published 04 October 2018

ABSTRACT

Considering the importance of sunflower crop and its versatility in the world market, this study aimed to evaluate the physiological quality of sunflower seeds subjected to different doses of biostimulant (0.009% kinetin, 0.005% indolebutyric acid and 0.005% gibberellic acid) under stress conditions. The experiment was carried out at the Federal University of Viçosa, using the cultivar Hélio 250. The studied factors consisted of biostimulant doses (0, 2, 3, and 5 mL kg^{-1}), water retention capacities (40, 60 and 90%), and osmotic potentials (0.0, -0.2 and -0.4 MPa). Seeds were pre-soaked with solutions of 0.009% kinetin, 0.005% indolebutyric acid and 0.005% gibberellic acid for 4 hours and then tested for germination and vigour. The study was divided into three trials: 1. Biostimulant x field capacity; 2. Biostimulant x osmotic potential; both in a completely randomised design (CRD), with factorial scheme 5x3; and 3. Biostimulant x Temperature, in CRD, with a 5 x 2 factorial arrangement

**Corresponding author: E-mail: veimar26@hotmail.com;*

and four replications. After collection, data were tested by Analysis of Variance and regression in the statistical program SISVAR. Under the water and osmotic stress conditions, the biostimulant action was maximised, demonstrating superior performance in the doses of 3 and 4 mL. There was an increase for both the dry mass of the root at all doses of the biostimulant and for the dry mass of the area part in potentials -0.2 and - 04 in the use of PEG6000. The stress given by PEG 6000 promoted an increase in the dry mass of the root in all the doses of the biostimulant, and for the dry matter of the aerial part, there was a progressive increase of the potentials -0.2 and -0.4.

Keywords: Water deficiency; biostimulant; Helianthus annuus; polyethylene glycol; temperature.

1. INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the four largest vegetable oil producing crops in the world. Its world production in 2014 was 41.34 million tons, with Brazil contributing 158.56 thousand tons of this production [1]. The commercialisation of sunflower has a growing demand of 13% per year, which involves the market for oil, animal feed and biofuel production [2].

Although there is a great demand for sunflower cultivation, like many other economically important plants, its production is limited by biotic and abiotic stresses that cause production decrease in traditional cropping regions [3].

One of the alternatives to minimise the negative response of plants to stress and to increase productivity is the use of biostimulants, which favour nutrient absorption and efficiency, abiotic stress tolerance and crop quality [4].

The application of growth regulators in the early stages of plant growth contributes to root development, rapid recovery after exposure to water stress, increases resistance to pests and diseases, and helps plant establishment, enhancing absorption and yield of crops [5]. Other authors have also reported the beneficial effects of biostimulants in cultivated plants such as pea, tomato and corn [6], almond [7] and beans [8].

Given benefits of the application of biostimulant and the response under stress conditions, there has been done a little research on the action of plant hormones on the germination and vigour of the sunflower seeds, thus evidencing the need for more studies to confirm its action. Thus, the goal of this study was to evaluate the physiological quality of sunflower seeds subjected to different doses of biostimulant and stress conditions.

2. MATERIALS AND METHODS

The experiment was carried out between April and June 2017, at the Laboratory of Seed Analysis of the Department of Plant Science at the Federal University of Viçosa, State of Minas Gerais (20°45'14" latitude, 42°52'53" longitude and 690 m altitude). The cultivar of sunflower used was Helio 250 from the company Heliagro Agricultura e Pecuária Ltda., harvested in 2015.

Seeds were initially analysed for the moisture content according to Dutra et al. [9], where moisture content of 9% was verified. Subsequently, seeds were pre-soaked for 4 hours in solutions with biostimulant (0.009% kinetin, 0.005% indole butyric acid and 0.005% gibberellic acid) except for the control, which was pre-soaked only in water. They were then allowed to dry at room temperature for 12 hours.

The study was divided into three trials. The initial trial [Biostimulant (Biost) x Field Capacity (CC)] was developed in a completely randomised design (CRD), with four replications, in a 5x3 factorial arrangement. The first factor corresponded to five doses of biostimulant: 0; 2; 3; 4 and 5 mL Kg^{-1}. The second factor evaluated three water retention capacities: 40%, 60% and 90%. The field capacity was obtained using a methodology used by Brazilian ministry of Agriculture [10].

The tests conducted were: Emergence test (E) - conducted in the seed analysis laboratory, using 50 seeds, for each replication. These were sown at a depth of 2 cm in plastic trays containing washed and sterilised sand. Sand was moistened with an amount of water corresponding to 40, 60 and 90% of the water retention capacity of the substrate. Count of emerged seedlings was performed on the 14^{th} day after sowing. The results were expressed as a percentage [11]. Emergence Speed Index (ESI) - determined in conjunction with the emergence test. Seedlings were counted every

day until stabilisation of the number of seedlings. The emergence speed index of the seedlings was calculated according to Maguire [12]. Dry matter of emerged seedlings (DMES) - normal seedlings obtained from the emergence test was evaluated. The replications of each treatment were placed in identified paper bags and taken to the forced air oven, maintained at a temperature of 60 ± 5°C until reaching the constant mass. After this period, each repetition had the mass determined on a scale accurate to 0.001g, and the mean results were expressed in milligrams per seedling [13].

Trial 2 [Biostimulant (Biost) x Polyethyleneglycol (PEG 6000)] was carried out in a completely randomised design, with four replications, in a 5x3 factorial arrangement. The first factor corresponded to five doses of biostimulant: 0; 2; 3; 4 and 5 mL Kg^{-1}. The second factor evaluated three osmotic potentials: 0.0; -0.2 and -0.4 MPa.

The following tests were carried out: Determination of the degree of moisture - by the greenhouse method (105°C ± 3°C), for 24 hours with results expressed as a percentage, according to the Rules for Seed Analysis [10]. Germination test (G) - four replications of 50 seeds were sown on germitest paper rolls moistened with solutions of polyethylene glycol 6000, equivalent to 2.5 times the mass of the non-hydrated paper and kept in biochemical oxygen demand (BOD) under the temperature of 25°C. Normal seedlings were counted on the tenth day after the test, and the results were expressed as a percentage of normal seedlings 10]. First germination count test (FGC) – was performed in conjunction with the germination test, considering the percentage of normal seedlings present on the 4^{th} day after the test setup [13]. Seedling length (SL) -the average length of normal seedlings obtained by sowing four replicates of 10 seeds on germitest paper rolls moistened with polyethylene glycol (PEG 6000) solutions equivalent to 2.5 times the mass of the non-hydrated paper and maintained in biochemical oxygen demand (BOD) at 25°C for 7 days. Length of the root (LR) and shoot (LS) of normal seedlings was measured using a millimetre ruler, with results in $mm.seedling^{-1}$ [13]. Dry matter of shoot (SDM) and root (SDR): after separation, shoot and root were oven-dried at 60 ± 5°C to constant mass; and then weighed. The results were given in $mg.\ seedling^{-1}$ [13].

Trial 3 was performed in a completely randomised design, with four replications, in a 5x2 factorial arrangement. The first factor corresponded to five doses of biostimulant: 0; 2; 3; 4 and 5 mL Kg^{-1}. The second factor evaluated two temperatures: 10 and 25°C. The tests were: Cold test (F), in which the seeds were sown on moistened germitest paper rolls and kept at 10°C for seven days. After this period, the rolls were transferred to a temperature of 20-30°C, and the evaluations were carried out on 4^{th} and 10^{th} day [14]. Germination test (G) - four replications of 50 seeds were sown on moistened germitest paper rolls with solutions of polyethylene glycol 6000, equivalent to 2.5 times the mass of the non-hydrated paper and kept in biochemical oxygen demand (BOD) under the temperature of 25°C. Normal seedlings were counted on the 10^{th} day after installing the test, and the results were expressed as the percentage of normal seedlings [10].

With the obtained data, the interactions Biostimulant x PEG 6000, Biostimulant x Field Capacity and Biostimulant x Temperature were analysed and when significant ($p < 0.05$), the necessary breakdown was performed. The means were compared by the regression test ($p < 0.05$), with the aid of the software System for Analysis of Variance - SISVAR.

3. 3. RESULTS AND DISCUSSION

3.1 1° Trial - Interaction Biostimulant X Field Capacity

There was no significant effect on seedling emergence (E) (Table 1). For the Emergence Speed Index, it was observed that in field capacity 60% and 90% there was an increase in the index up to the dose 4 mL, beginning to decrease afterwards (Fig. 1, Table 2). The increased availability of water associated with the biostimulant may have promoted a stimulus, with the action of gibberellin, in the synthesis of enzymes that degrade nutrient reserves stored in the endosperm, forming simple sugars, amino acids and nucleic acids, which provide food and energy for seedling growth [15]. This process favours cell elongation, which results in the coat rupture and root emergence, accelerating germination with greater uniformity [16]. This rapidity stimulated by the regulators in the emergence is important because the longer the germination of the seed, the more prone it will be to injuries due to pests or diseases present in the soil, compromising the integrity of the embryo [17].

Table 1. Summary of Analysis of Variance for emergence percentage (E), Emergence Speed Index (ESI) and dry matter of emerged seedlings (DMES), subjected to seed treatment with different doses of biostimulant and field capacities

SV	DF	QM		DMES (mg.seedling^{-1})
		E (%)	ESI (%)	
Biost	4	9.73^{ns}	1.29**	3.19**
CC	2	2.60^{ns}	2.73**	26.07**
Biost*CC	8	8.93^{ns}	1.43**	0.86^{ns}
Error	45	5.73	0.15	0.54
C.V. (%)		2.45	3.61	5.11
Mean		97.80	10.89	14.4

*^{ns}Non-significant, and *Significant at 5% probability by F-test. Biostimulant (Biost), field capacity (CC), coefficient of variation (CV), mean square (MS), interaction between biostimulant and field capacity (Biost*CC).*

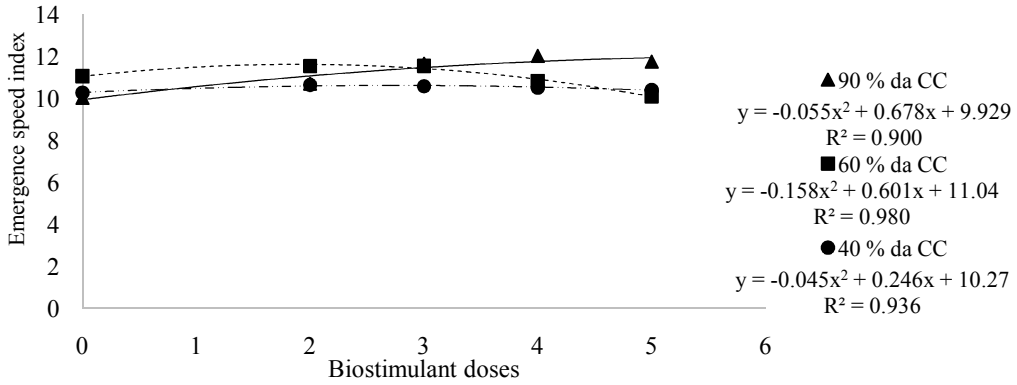

Fig. 1. Response of the emergence speed index of seedlings subjected to biostimulant doses and different field capacities

Table 2. Mean values of the biostimulation x field capacity interaction breakdown for emergence speed index (ESI)

Biostimulant	Field capacity		
	ESI		
	90%	60%	40%
0	10.02 B	11.05 A	10.26 B
2	10.70 B	11.52 A	10.40 B
3	11.64 A	11.54 A	10.50 B
4	12.02 A	10.83 B	10.57 B
5	11.55 A	10.09 B	10.64 B

Mean values followed by different letters, by Tukey's test at 5% probability

For the dry matter of emerged seedlings (DMES) (Figs. 2 and 3), there was a significant effect of the isolated factors. The higher water availability implied in the maximum absorption of water and consequently higher weight of the dry mass. Similar results were reported by Dutra et al. [9], with the EMBRAPA 122/V-2000 sunflower, in which they concluded that under conditions of water availability of 80 to 100% water retention capacity, the cultivars showed better performance than when subjected to 60% field capacity.

For the doses of biostimulant, the DMES (Fig. 3) exhibited increasing behaviour up to the dose of 4 mL. Thereafter, a decline at 5 mL was found, representing a 9% drop in DMES in relation to the maximum concentration applied. Thus, up to the 4 mL dose, the biostimulant promoted better seedling performance. Santini et al. [18] also noticed that the treatment of soybean seeds with biostimulants favoured the shoot dry matter of the plant.

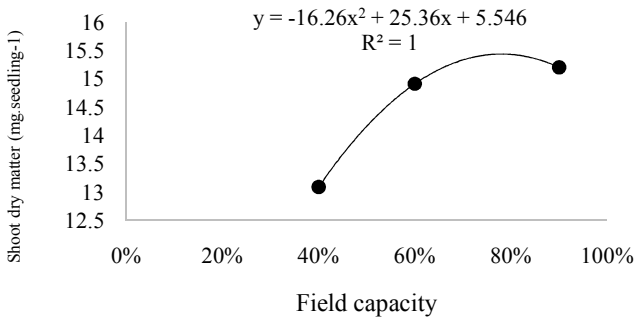

Fig. 2. Response of the shoot dry matter of emerged seedlings subjected to different field capacities

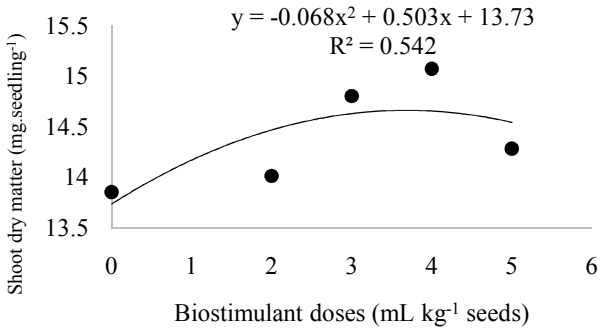

Fig. 3. Response of the shoot dry matter of emerged seedlings subjected to different doses of biostimulant

3.2 2° Trial– Interaction Biostimulant X Polyethylene Glycol 6000

There was a significant effect of the Biostimulant (Biost) x Polyethylene glycol 6000 (PEG 6000) interaction, for germination (G), first germination count (FGC), shoot length (LS), root length (LR) and dry matter of root (SDR) and dry matter of emerged seedlings (DMES (Table 3).

For germination and first count (Fig. 4 and 5, Table 4), there was an upward trend up to a maximum of 4 and 3 mL, respectively, decreasing after these doses, thus, at potentials -0.2 and -0.4, the dose of 5 mL showed less efficiency for the response of these variables. The stress condition provided by these two potentials may have contributed to the 5 mL dose starting to cause seed toxicity, impairing vigour and germination, since the hormones can promote or inhibit changes in the plant, for this to occur, there must be sufficient quantity in the appropriate cells for desired physiological effect [19]. It was also observed that in conditions without the application of PEG 6000, there was greater uniformity of G and FGC at all doses studied.

In the osmotic potential -0.4 of the first germination count (Fig. 5), a mean of 0 was observed at all doses, due to the lower availability of water for the seed. The interference on vigour may be the response to high viscosity caused by the mixture of polyethylene glycol, whose general formula is $HOCH_2(OCH_2CH_2)_nOH$, and water that moistens the substrate, limiting the availability of oxygen to the seeds [20]. This action has a negative effect on sunflower germination processes that depend on the presence of water and oxygen for the proper functioning of plant metabolism [21].

For shoot length (LS) (Fig. 6), a rising curve was observed in all osmotic potentials up to the 4 mL dose when there was a reduction in biostimulant efficiency in most of the potentials studied. This may possibly be justified by phytotoxicity of the embryo, which at doses of 5 mL maximises negative effects of abiotic stress, by decreasing the efficiency of the plant hormones used [17].

Thus, the beneficial action of the biostimulant in the stress situation caused by PEG 6000 is noted. Marques et al. [22], concluded that applications of hormones directly on the seeds promoted the emergence of vigorous seedlings with a longer length.

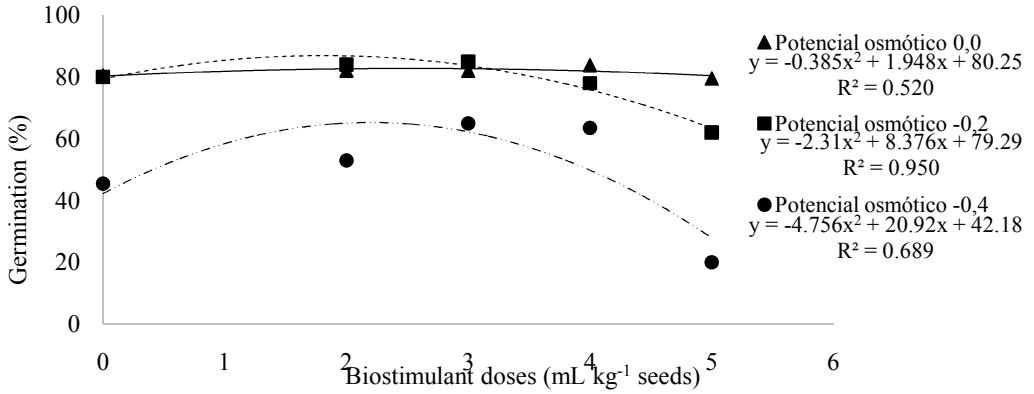

Figure 4. Response of germination of seedlings subjected to biostimulant doses and different osmotic potentials

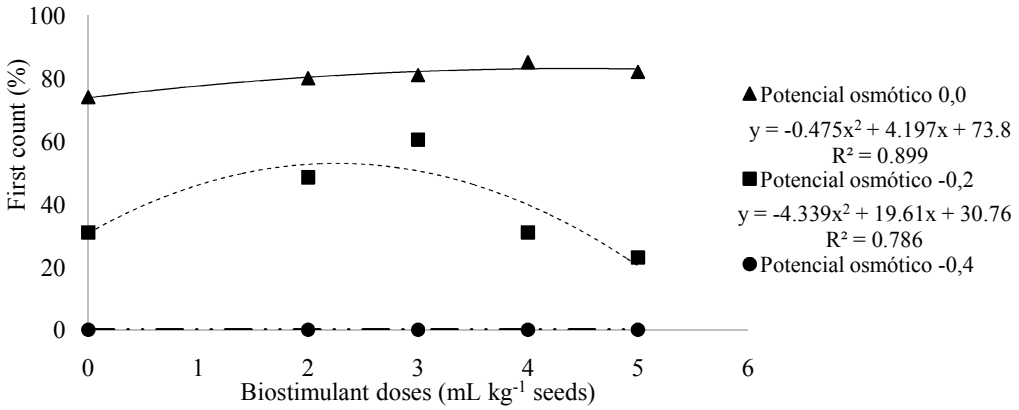

Fig. 5. Response of the first count of seedlings subjected to doses of biostimulant and different osmotic potentials.

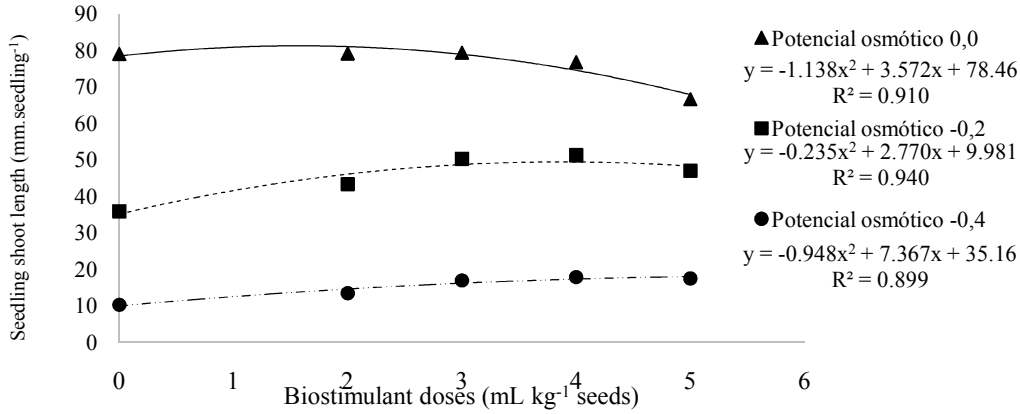

Fig. 6. Shoot length of seedlings subjected to doses of biostimulant and different osmotic potentials

Table 3. Summary of Analysis of Variance for the germination percentage (G), first germination count (FGC), seedling shoot length (LS), primary root length (LR), dry matter of emerged seedlings (DMES), root dry matter (SDR), subjected to the treatment of seeds with different doses of biostimulant and osmotic potential

SV	DF	QM					
		G (%)	FGC (%)	LS (mm.seedl^{-1})	LR (mm. seedl^{-1})	DMES (mg. seedl^{-1})	SDR (mg. seedl^{-1})
Biost	4	1068.4**	331.4**	116.7*	3015.2**	1.3^{ns}	1.5^{ns}
PEG 6000	2	6247.6**	32415.2**	18592.9**	5055.1**	246.6**	77.1**
Biost*PEG 6000	8	318.7**	337.4**	101.1*	1473.2**	2.9^{ns}	2.4**
Error	45	46.0	35.0	34.7	132.6	1.2	0.8
C.V. (%)		9.7	14.9	12.9	12.4	12.7	16.0
Mean		69.7	39.7	49.6	92.6	8.6	5.6

^{ns}Non significant, *Significant at 5% and ** Significant at 1% probability by F-test. Seedling (seedl), Biostimulant (Biost), polyethylene glycol (PEG 6000), Interaction between Biostimulant and polyethylene glycol (Biost x PEG 6000)

Table 4. Mean values of the biostimulation x polyethylene glycol interaction breakdown for germination (G), first germination count (FGC), root dry matter (RDM) root length (RL) and length of the air part (LAP)

Biost	PEG 6000								
	G			FGC			RDM		
	0	-0.2	-0.4	0	-0.2	-0.4	0	-0.2	-0.4
0	80 A	80 B	45 B	74 A	31 B	0 C	7 A	5.72 B	2.42 C
2	82 A	84 A	53 B	80 A	48 B	0 C	7 A	6.47 A	2.42 B
3	82 A	85 A	65 B	81 A	60 B	0 C	6 A	6.67 A	3.57 B
4	83 A	78 A	63 B	85 A	31 B	0 C	6 A	6.90 A	4.05 B
5	75 A	62 B	20 C	82 A	23 B	0 C	6 A	7.63 A	4.45 C
Biost	**LR**			**LS**					
	0	**-0.2**	**-0.4**	**0**	**-0.2**	**-0.4**			
0	73.25 B	35.42 C	93.00 A	79.00 A	35.86 B	10.25 C			
2	81.07 B	78.47 B	103.2 A	79.15 A	43.32 B	13.42 C			
3	83.40 B	102.15 AB	110.62 A	79.37 A	50.30 B	16.97 C			
4	83.05 B	118.47 A	111.0 A	76.7 A	51.30 B	17.65 C			
5	66.32 B	122.00 A	127.92 A	66.6 A	47.00 B	17.50 C			

Mean values followed by different letters, by Tukey's test at 5% probability

As for the root length (LR) (Fig. 7), the maximal effect of the hormones kinetin, gibberellin and indolebutyric acid occurred under stress conditions promoted by PEG 6000, which contained low water availability. This result was due to the water stress, which often negatively interferes with stem growth and leaf expansion but increases root elongation [15]. This, associated with the action of the doses of biostimulant, favoured the development of the root system, resulting in a larger length in this variable. Other authors have obtained similar results, where the application of plant stimulants favoured root growth, exhibiting rapid recovery after exposure to water stress [23,24,21].

For the root dry matter (RDM) (Fig. 8), there was an increase in the production at all doses of the biostimulant when subjected to stress with PEG, which did not occur in the osmotic potential 0. This confirms the previous results for LR and may have been due to the presence of plant hormones contained in the biostimulant that provides the capacity to stimulate root growth, increasing the assimilation of water and nutrients, thus favouring the balance of seedling metabolism [15]. Oliveira et al. [20] observed that biostimulant doses promoted higher root growth in corn plants and were subjected to different osmotic potentials. This result is pertinent since plants with a well-developed root system show better performance when exposed to osmotic stress.

Concerning the shoot dry matter (SDM) (Fig. 9), there was the only effect for the PEG 6000 factor, with a progressive increase in potentials -0.2 and -0.4, the latter being the maximum response point of this characteristic. This result is the inverse of the LS and can be explained by that, the cells have signalling molecules, which under stress conditions are activated by distension, causing some situational changes in the seedling volume as a stress defence mechanism to which it was subjected [15].

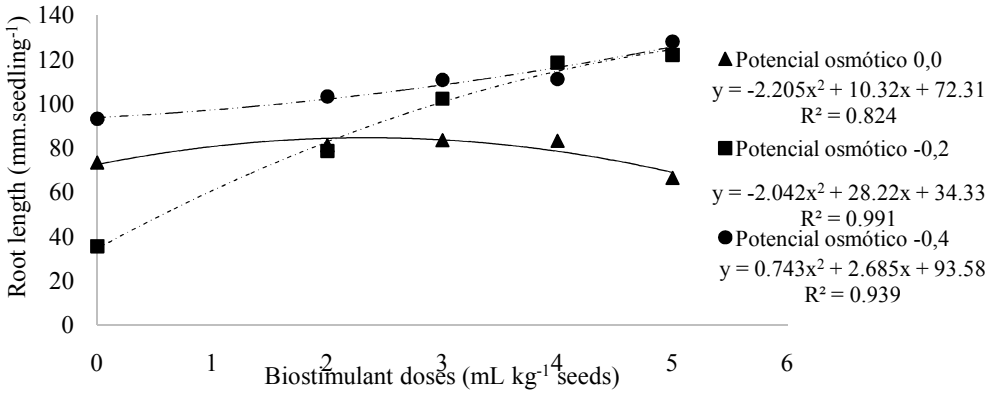

Fig. 7. Root length of seedlings subjected to doses of biostimulant and different osmotic potentials

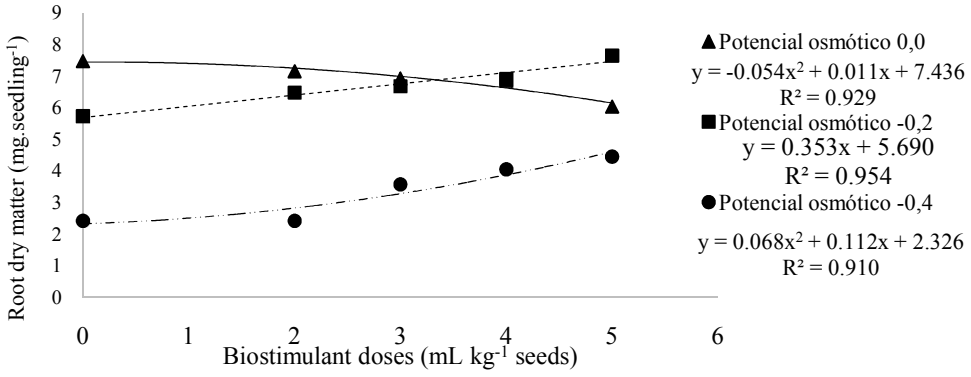

Fig. 8. Root dry matter of seedlings subjected to doses of biostimulant and different osmotic potentials

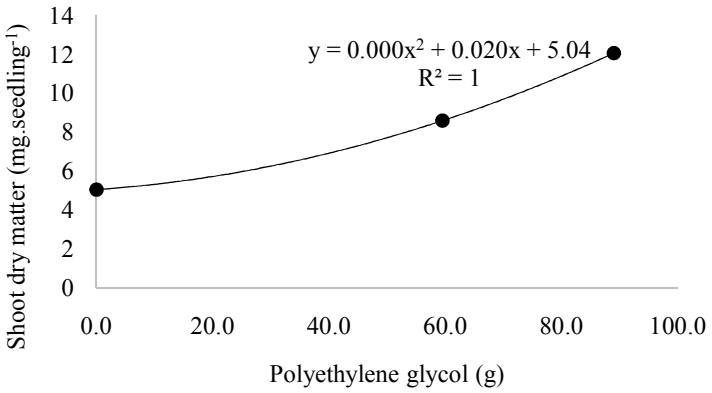

Fig. 9. Shoot dry matter of seedlings subjected to doses of biostimulant and different osmotic potentials

3.3 3° Trial –Biostimulant X Temperature Interaction

The number of normal seedlings (SN) (Table 5) was significantly influenced by temperature. A higher presence of normal seedlings at a lower temperature was observed (Fig. 10). This response can be explained by the maximisation of the genotype expression under adverse situation associated with the biostimulant, promoting good results in the number of SN. Thus, there may have been a positive stimulus of the hormones used in the seeds exposed to the low temperature, thus increasing the stress tolerance and consequently improving the potential of the crop [25].

Table 5. Summary of analysis of variance for normal seedlings subjected to seed treatment with different doses of biostimulant and temperatures

SV	DF	QM
		SN
Biost.	4	77.77^{ns}
Temp.	1	855.62*
Biost*Temp.	4	71.87^{ns}
Error	30	59.36
C.V. (%)		8,94
Mean		86.17

^{ns}Non-significant and *Significant at 5% probability by F-test

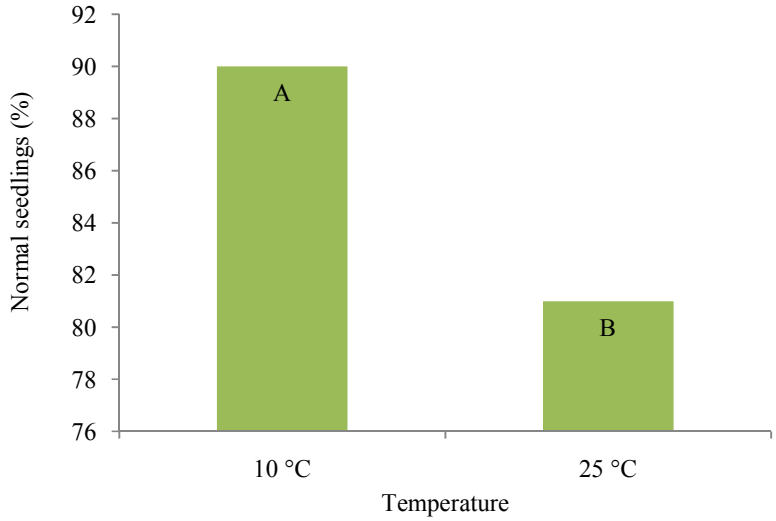

Fig. 10. Normal seedlings subjected to biostimulant doses and temperatures

Despite the absence of normal seedlings at the first count, no fungal infection was observed in the seeds, which probably contributed to the high percentage of normal seedlings in the second count. After changing the temperature, the plants germinated obtaining good results. In a study by Dourado et al. [8] showing the application of biostimulant on corn and beans, the authors concluded that under stress conditions, biostimulants can maximise their effects, since they are constituted by hormones that can be beneficial in plant defence and the growth and development of plants.

4. CONCLUSION

The use of biostimulant at 3 and 4 mL increased mostly early growth traits of the seedlings under the experimental conditions of the present study, both when exposed to different water retention capacities and at different osmotic potentials.

The biostimulant maximises the germination potential of sunflower seeds subjected to low temperatures.

The stress submitted by PEG 6000 promotes an increase in root dry matter in all doses of the biostimulant. For the aerial part dry matter there was a progressive increase of the potentials -0.2 and -0.4 in PEG 6000 use.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. Food and Agricultural Organization. FAOSTAT – Statistics Database; 2014. Available:http://www.fao.org/faostat/en/#home (Acesso em: 25/06/2017)
2. Araújo JL, Oliveira ES, Teixeira FN. *In vitro* alternative control of sclerotium rolfsii in sunflower (*Helianthus annuus* L.) by the use of plant extracts and *Trichoderma* spp. Essentia Magazine. 2014;15(2):25-35.
3. Moreira MAB, Lira MA, Alves MCS, Talamini V. Occurrences of fungal diseases in the sunflower crop in Rio Grande do Norte. Technical Communiqué. 2017;95. Available:http://www.cpatc.embrapa.br/publicacoes_2009/cot_95.pdf (Acesso em: 20/06/2017)
4. EBIC. European Biostimulants Industry Council. About biostimulants and the benefits of using them; 2017. Available:http://www.biostimulants.eu/about/what-are-biostimulants-benefits/ (Acesso em: 20/06/2017)
5. Dantas ACVL, Queiroz JMO, Vieira EL, Almeida VO. Effect of gibberellic acid and the biostimulant Stimulate® on the initial growth of thamarind. Revista Brasileira de Fruticultura. 2012;34(1):008-014.
6. Colla G, Rouphael Y, Canaguier R, Svecova E, Cardarelli M. Biostirnulant action of a plant-derived protein hydroly sate produced through enzymatic hydrolysis. Frontiers in Plant Science. 2014;5(448).
7. Saa S, Olivos-Del Rio A, Castro S, Brown PH. Foliar application of microbial and plant based biostimulants increases growth and potassium uptake in almond (*Prunus dulcis* Mill. D. A. Webb). Frontiers in Plant Science. 2015;6(87).
8. Dourado Neto D, Dario GJA, Barbieri APP, Martin TN. Biostimulant action on agronomic efficiency of corn and common beans. Bioscience Journal. 2014;30(1): 371-379.
9. Dutra CD, Prado EAF, Paim LR, Scalon SPQ. Development of sunflower plants under different conditions of water supply. Semina: Agrarian Sciences. Development of Sunflower Plants under Different Conditions of Water Supply. 2012;33(1): 2657-2668.
10. Brazil. Ministry of agriculture, livestock and supply. Rules for seed analysis. Brasília, MAPA / ACS. 2009;395.
11. Rocha CRM, Silva VN, Cicero SM. Sunflower seed vigor evaluation by seedling image analyze. Rural Science. 2015;45(6):970-976.
12. Maguire JD. Speed of germination-aid in relation evaluation for seedling emergence vigor. Crop Science. 1962;2(2):176-177.
13. Nakagawa J. Vigor tests based on seedling evaluation. In: Krzyzanowski FC, Vieira RD, France-Neto JB. (Ed.). Seed vigor: Concepts and tests. Londrina: ABRATES. 1999;2.1-2.21.
14. Braz MRS, Rosseto CAV. Correlation between sunflower seeds quality evaluation tests and seedling emergence in field. Ciência Rural. 2009;39(7):2004-2009.
15. Taiz L, Zeiger E. Fisiologia vegetal. 5. ed. Porto Alegre, Artmed. 2013;918.

16. Stenzel NMC, Murata IM, Neves CSVJ. Overcoming atemoya and custard apple seed dormancy. Revista Brasileira de Fruticultura. 2003;25(2):305-308.
17. Couto CA, Peixoto CP, Vieira EL, Carvalho EV, Peixoto VAB. Action of cinetina, butyric acid and gibberellic acid on the emergency of sunflower under aluminum stress. Comunicata Scientiae. 2012;3(3): 206-209.
18. Santini JMK, Perin A, Santos CG, Ferreira AC, Salib GC. Technical-economical viability of the use of biostimulants in soybean seeds. Agricultural Science and Technology. 2015;9(1):57-62.
19. Salisbury FB, Ross CW. Fisiología vegetal. 4. Ed. São Paulo, Cengage Learning. 2013;792.
20. Oliveira AB, Gomes-Filho E, Enéas-Filho J. Priming and factors affecting this technique: Aging of seeds and abiotic stress. Encyclopedia Biosphere. 2010; 6(11).
21. Santos CAC, Peixoto CP, Vieira EL, Silva MR, Bulhões IJ, Santos JMS, Carvalho EV. Sunflower productivity under the action of plant biostimulant in different sowing conditions in the no-tillage system. Revista de Ciências Agroambientais. 2016;14(2).
22. Marques MER, Simonetti APMM, Rosa HA. Aspect's productive use of bio-stimulants culture soy. Acta Iguazu. 2014; 3(4):155-163.
23. Silva MJR, Bolfarini ACB, Rodrigues LFOS, Ono EO, Rodrigues JD. Seedling formation of watermelon in function of different concentrations and forms of application of mixture of plant regulators. Scientia Plena. 2014;10(10).
24. Santos CAC, Peixoto CP, Vieira EL, Carvalho EV, Peixoto VAB. Stimulate® in seed germination, seedling vigor and emergence of sunflower. Bioscience Journal. 2013;29(2):605-616.
25. Van Oosten MJ, Pepe O, De Pascale S, Silletti S, Maggio A. The role of biostimulants and bioeffectors as alleviators of abiotic stress in crop plants. Chemical and Biological Technologies in Agriculture. 2017;4(5).

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/26504