MARQUES, M. G.; SILVA, A. T.; MARTINS, A. S.; ARRUDA, N.; BENETT, K. S. S.; BENETT, C. G. S. Effects of boron application on the physiological potential of stored sunflower seeds. **Revista de Agricultura Neotropical**, Cassilândia-MS, v. 10, n. 4, e7421, Oct./Dec, 2023. ISSN 2358-6303. DOI: https://doi.org/10.32404/rean.v10i4.7421.

Effects of boron application on the physiological potential of stored sunflower seeds

Marina Gabriela Marques[1], Amanda Tavares da Silva[1], Anne Silva Martins[1], Natália Arruda[1], Katiane Santiago Silva Benett[1], Cleiton Gredson Sabin Benett[1]

[1] Goiás State University, Ipameri University Unit, Ipameri, Goiás, Brazil. E-mail: magabimarques@hotmail.com, amandaagro22@gmail.com, annemartins.agro@gmail.com, nathy.a@hotmail.com, katiane.benett@gmail.com, cleiton.benett@gmail.com

Received: 09/03/2023; Accepted: 22/09/2023.

ABSTRACT

The objective of this study was to assess the physiological quality of sunflower seeds as a function of boron rates and seed storage times. The experiment was conducted at the Seed Laboratory of the State University of Goiás, Ipameri campus, Goias, Brazil. A completely randomized experimental design was used, in a 6×6 factorial arrangement, with four replications. The factors consisted of six boron rates (0, 1, 2, 3, 4, and 5 kg ha^{-1}) manually applied to the soil using boric acid (17%), and six seed storage times (0, 2, 4, 6, 8, and 10 months). The seeds used were from plants grown in 2017 as a second crop, which was fertilized according to the boron treatments. The following evaluations were conducted after harvesting for each seed storage time: germination test, first germination count, accelerated aging test, total germination, seed moisture content, seedling length and dry weight, 1,000-seed weight, and tetrazolium test. Boron rates and storage times had positive effects on most analyzed variables. The most adequate boron rate found was 2 to 3 kg ha^{-1}, with no effect of seed storage times on the physiological quality of sunflower seeds.

Keywords: Viability, Soil fertilization, Post-harvest, *Helianthus annuus* L., Conservation.

Influência da adubação boratada sobre o potencial fisiológico de sementes de girassol armazenadas

RESUMO

Objetivou-se neste trabalho avaliar a qualidade fisiológica de sementes de girassol, em função da adubação boratada e tempos de armazenamento. O trabalho foi desenvolvido no Laboratório de Sementes da Universidade Estadual de Goiás, Unidade Universitária de Ipameri. O delineamento experimental utilizado foi inteiramente casualizado, arranjado em esquema fatorial 6 x 6, com quatro repetições. O primeiro fator refere-se às doses de boro, as quais foram utilizadas seis doses (0, 1, 2, 3, 4 e 5 kg ha^{-1}), aplicadas via solo manualmente utilizando como fonte de boro o ácido bórico (17%). O segundo fator refere-se aos tempos de armazenamento (pós-colheita, 2; 4; 6; 8 e 10 meses de armazenamento). As sementes utilizadas foram oriundas de plantas cultivadas na safrinha de 2017 e adubadas conforme os tratamentos com as doses de boro. Após a colheita foram realizadas as seguintes avaliações em cada tempo de armazenamento: teste de germinação, primeira contagem de germinação, envelhecimento acelerado, índice de velocidade de germinação, condutividade elétrica, peso de 1000 sementes e teste de tetrazólio. As doses de boro e tempo de armazenamento apresentaram influência positiva para a maiorias das variáveis analisadas, sendo que a dose mais adequada neste estudo foi entre 2 e 3 kg ha^{-1} de boro não afetando o tempo de armazenamento sobre a qualidade fisiológica de sementes.

Palavras-chave: Viabilidade, Adubação, Pós-colheita, *Helianthus annuus* L., Conservação.

1. Introduction

Sunflower (*Helianthus annuus* L.) is a crop species used for both human and animal consumption that has a high economic importance, which makes growers to choose it as a second crop in Brazil.

It is an annual dicotyledonous plant species native to North America, belonging to the Asterales order and the Asteraceae family. Sunflower is one of the most important oilseed species that produce edible vegetable oils (Talamini et al., 2011). Sunflower is an oilseed species that presents tolerance to drought, cold, and pests; this agronomic characteristic explains its adaptability to the different edaphoclimatic conditions of Brazil, as it is grown in all regions of the country (Nunes et al., 2016).

Information on aspects related to mineral nutrition and fertilizers is essential for successful sunflower crops, including the nutrient absorption rate, which is significant for defining fertilizer application strategies to crops (Zobiole et al., 2010; Freitas et al., 2021). Improper use of micronutrients, mainly using inappropriate application methods, is among the main limiting factors for crop yields (Baraich et al., 2016). Foliar application of minerals such as Zn, B, and Fe has been considered more effective compared to soil application due to their adsorption to soil particles and less contact with plant roots (Wissuwa et al., 2008).

The quality of seeds used to implement a crop is an essential factor for achieving an adequate plant stand (Haesbaert et al., 2017). According to Scheeren et al. (2010), knowing the seed quality before sowing is the most accurate and safe procedure to avoid increases in crop production costs. The interaction between genetic, physical, physiological, and sanitary components determines the seed quality (Talamini et al., 2011). The use of seed vigor tests is essential for monitoring seed quality from physiological maturation, as a decreased vigor indicates viability loss (Dias and Marcos Filho, 1995). Therefore, the objective of this study was to evaluate the physiological quality of sunflower seeds as a function of boron rates and seed storage times.

2. Material and Methods

Sunflower seeds of the variety Aguará 4, developed by Atlântica Sementes company, were obtained in an experimental field implemented in the 2017 second crop at the agricultural area of the State University of Goiás, Ipameri, Goiás, Brazil (17°43'04"S, 48°08'43"W, and altitude of 794 m).

A completely randomized experimental design was used, in a 6×6 factorial arrangement, with four replications. The factors consisted of six boron rates (0, 1, 2, 3, 4, and 5 kg ha^{-1}), manually applied to the soil as topdressing, using boric acid (17%), and six seed storage times: 0 (M0), two (M2), four (M4), six (M6), eight (M8), and ten (M10) months. The seeds were packed in Kraft paper bags and stored at room temperature.

Seed moisture content was determined after harvesting and seed processing, using two subsamples of four grams of sunflower seeds, which were placed in an oven at 105 °C for 24 hours (Brasil, 2009) and, subsequently, subjected to laboratory evaluations.

Germination test was conducted using 200 seeds divided into four 50-seed replications. Germitest filter paper was used as substrate. The rolls were placed in plastic bags and placed at 45° angle inside a germinator maintained at a constant temperature of 25 °C. The count was performed on the tenth day after the beginning of the test by counting normal seedlings, considering as germinated, the seeds that produced normal seedlings (Brasil, 2009). The results were expressed as mean percentage of normal seedlings. The first germination count was carried out simultaneously to the germination test, following the recommendations of Brasil (2009).

The accelerated aging test was conducted using four 50-seed replications, placed transparent plastic boxes (11×11×3.5 cm). These boxes were covered and placed in a germination chamber at 41 °C for 48 hours (Marcos Filho, 2005). The seeds were placed for germination following the methodology described for germination tests, and evaluated on the fourth day; the results were expressed as percentage of normal seedlings.

One thousand seed weight (g) was determined by directly weighing the achenes on a precision balance, using eight 100-seed replications, and multiplying the means by 10 (Brasil, 2009).

Tetrazolium test was conducted according to the methodology proposed by the Rules for Seed Analysis, using 100 seeds divided into four 25-seed replications. After staining, the seeds were rinsed in running water and then evaluated (Brasil, 2009).

Seedling length was evaluated using four replications of 25 normal seedlings from each treatment. The evaluated seedlings were from the germination test, which was completed on the tenth day. Total seedling length (cm) was measured from the root tip to the cotyledon base. Dry weight was determined using normal seedlings, without the cotyledons, that were selected during the seedling length evaluation, which were weighed on a precision balance after drying, as described by Nakagawa (1999).

The data obtained were subjected to analysis of variance (F test) and the means were compared using the Tukey's test at 5% probability level. Regression analysis was performed for the boron rates. The statistical analyses were carried out using the program SANEST (Zonta et al., 1987).

3. Results and Discussion

The descriptive analysis of sunflower seed moisture content showed variations according to the evaluated seed storage times and boron rates. The lowest seed moisture content (6.2%) was found immediately after harvest (M0) and at six months of storage (M6), whereas the highest seed moisture contents were found at eight (M8) and four (M4) months of storage, which were 9.3% and 9.2%, respectively (Table 1). Seeds tend to lose the vigor and germination potential during storage due to lipid peroxidation, combined with high moisture content and temperature, indicating that seed moisture content affects the physiological quality of seeds during storage (Smaniotto et al., 2014).

The interaction between the factors (boron rate and seed storage time) had a significant effect on first germination count, total germination, accelerated aging test, seedling dry weight, and 1,000-seed weight. The storage time factor had a significant effect only on seedling length. However, the boron rates had no significant effect on seedling length and tetrazolium test (Table 2); thus, the discussion regarding these variables were focused on significant effects of the treatments and interactions for each variable.

First germination count was significantly affected by the interaction between seed storage time and boron rate only for the seed storage times M0 and M4. The data fitted to a quadratic regression, with an estimated boron rate of 3.00 kg ha^{-1} for M0. Regarding M4, the data fitted to an increasing linear model (Figure 1A). Germination was significantly affected by the interaction between boron rate and storage time only for the germination time M4, with the data fitting to an increasing linear model (Figure 1B). Contrastingly, Bonacin et al. (2009) evaluated the effect of boron rates on sunflower plants and found no significant effect on seed germination.

The interaction between boron rate and storage time had a significant effect on accelerated aging test (Figure 1C). The percentage of germinated plants for the seed storage times M0 and M10 presented a negative linear response as the boron rate was increased. Farinelli et al. (2006) found 89% seed vigor in the accelerated aging test for common bean seeds subjected to foliar application of boron and calcium.

Seedling dry weight was significantly affected by the interaction between seed storage times and boron rates only for the storage times M0 and M10. The seedling dry weight data for M0 fitted to a quadratic regression model with an estimated minimum boron rate of 2.57 kg ha^{-1}, whereas the data for M10 fitted to an increasing linear regression (Figure 1D). These results differ from those found by Marchetti et al. (2001), who found a significant effect of boron sources and rates (1, 2, and 4 mg dm^{-3}), with increasing rates leading to decreases in seedling dry weights.

Table 1. Sunflower seed moisture content (%) as a function of boron rates and seed storage times. Ipameri, GO, Brazil. 2017.

Boron rates (kg ha^{-1})	Seed storage time					
	M0	M2	M4	M6	M8	M10
0	8.1	7.1	8.3	7.6	9.3	8.2
1	6.2	8.2	7.1	6.2	6.6	8.5
2	8.1	8.8	7.2	7.8	7.7	7.2
3	8.8	6.7	6.7	7.6	7.6	8.6
4	7.2	8.4	9.2	8.5	8.4	6.6
5	7.7	8.4	6.6	7.2	7.0	7.2

M0 = immediately after harvest; M2 = two months of storage; M4 = four months of storage; M6 = six months of storage; M8 = eight months of storage; M10 = 10 months of storage.

Table 2. Analysis of variance for first germination count (FGC), total germination (G), accelerated aging test (AA), tetrazolium test (TZ), seedling length (SL), seedling dry weight (SDW), and 1,000-seed weight (TSW) of sunflower crops as a function of boron rates and seed storage times. Ipameri, GO, Brazil, 2017.

Source of variation	DF	FGC	G	AA	TZ	SL	SDW	TSW
Seed storage time (T)	5	1979.8*	506.12*	1455.62*	2.27^{ns}	13.13*	12.91*	16.89*
Boron rate (R)	5	3.32*	3.83*	18.89*	0.49^{ns}	0.65^{ns}	2.29*	15.06*
R×T	25	3.25*	3.27*	11.38*	1.00^{ns}	0.93^{ns}	1.76*	1.93*
CV (%)	---	4.67	5.34	4.01	6.48	13.89	10.89	8.80

DF = degrees of freedom; CV = coefficient of variation; * = significant at 5% probability level and ^{ns} = not significant as a function of application of boron rates and seed storage time.

Regarding 1,000-seed weight, the effect of the interaction between seed storage time and boron rate was significant only for M0, with the data fitting to a quadratic regression with an estimated minimum boron rate of 2.31 kg ha^{-1} (Figure 1C). The results found for boron rates contrast with those of Lima et al. (2013), who found significant effect of boron rates (1 to 5 kg ha^{-1}) on 1,000-achene weight.

According to Carvalho and Nakagawa (2012), seed weight may be associated with seed size, as larger seeds have higher amounts of reserve, resulting in higher growth and seedling dry weight, favoring plant development, resulting in higher yields for plants originating from lots of seeds with higher vigor according Braz and Rossetto (2009) and Toledo et al. (2009).

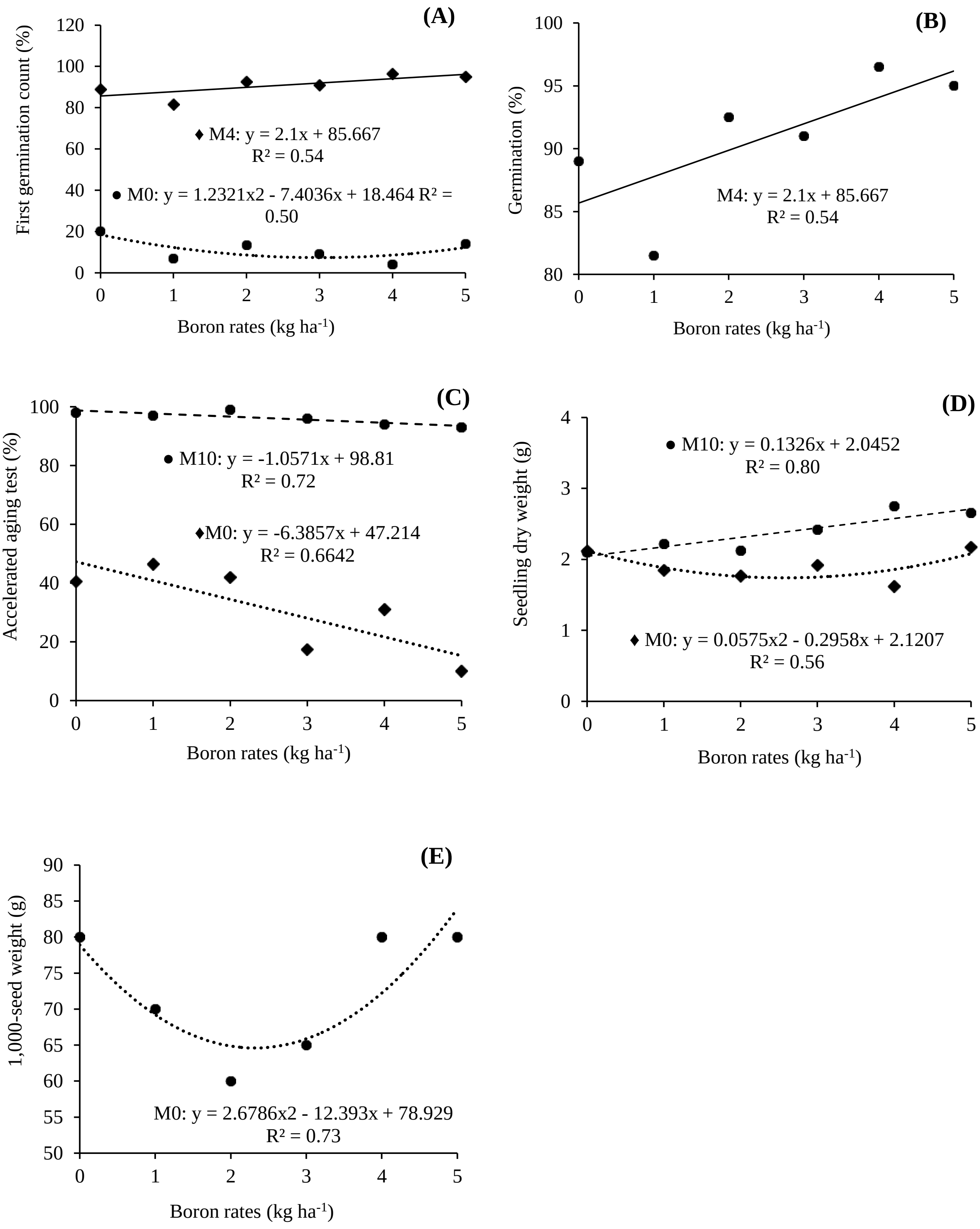

Figure 1. First germination count (A), total germination (B), accelerated aging test (C), seedling dry weight (D), and 1,000-seed weight (E) as a function of the interaction between seed storage time and boron rate culture sunflower. Ipameri, GO, Brazil, 2017.

The seed storage times had no significant effect on seed viability, according to the tetrazolium test, viable seeds ranged between 23.21% and 24.25%. The evaluated boron rates had no significant effect on the viability of seeds subjected to the tetrazolium test (Table 3). These findings are consistent with those of Silva et al. (2013), who assessed sunflower seed vigor through the tetrazolium test. However, Caldeira et al. (2014) reported that sunflower seed lots stored for four months presented similar germination speed index, initial germination count, and tetrazolium test results.

According to Silva et al. (2013), tetrazolium test can be used to assess sunflower seed vigor due to its high correlation with seedling emergence in the field and by providing reliability for seed lot classification. Seedling length was not significantly affected by boron rates (Table 3), but it was significantly affected by the seed storage times. Seedlings from seeds stored for ten months presented longer lengths, with a mean of 10.30 cm, however not significantly differing from those originated from seeds germinated immediately after harvest (mean of 9.34 cm).

The shortest seedling length (7.73 cm) was found for seeds stored for four months (M4), not differing from those stored for two (M2), six (M6), and eight months (M8). Seedling length is an important characteristic for differentiating seed lots. In general, longer seedling lengths correspond to lots of higher vigor seeds (Nakagawa, 1999). Thus, seedling length is a sensitive parameter for classifying seed lots with subtle differences in physiological potential (Guedes et al., 2009).

Table 3. Tetrazolium test and seedling length of sunflower seeds as a function of boron rates and seed storage times. Ipameri, GO, Brazil, 2017.

Seed storage time	Tetrazolium (%)	Seedling length (cm)
M0	94.64 a	9.34 ab
M2	93.16 a	8.65 bc
M4	92.84 a	7.73 c
M6	93.00 a	8.51 bc
M8	96.68 a	8.27 c
M10	97.00 a	10.30 a
Boron Rate (kg ha^{-1})	0	
0	91.68	8.62
1	96.16	9.13
2	98.48	8.75
3	96.00	8.67
4	91.64	8.94
5	97.16	8.67
CV (%)	6.48	13.89

M0-immediately after harvest; M2-two months of storage; M4-four months of storage; M6-six months of storage; M8-eight months of storage; M10-10 months of storage; CV-coefficient of variation. Means followed by the same lowercase letter in the column, for each evaluated factor, are not significantly different from each other by the Tukey's test at 5% probability level.

Therefore, the use of seed vigor tests is essential to assess characteristics that determine the potential for rapid and uniform emergence of normal seedlings under a wide range of environmental conditions (Marcos Filho, 2005). Additionally, the combination of application of boron rates and adequate seed storage times provides positive results for sunflower seed germination percentage.

4. Conclusions

The evaluated boron rates and seed storage times had significant positive effects on most of analyzed sunflower variables. The most adequate boron rate was between 2 and 3 kg ha^{-1}, with no effect of seed storage times on the physiological quality of sunflower seeds.

Authors' Contribution

Marina Gabriela Marques, Katiane Santiago Silva Benett, and Cleiton Gredson Sabin Bennet contributed to the research organization, conduction of experiments, data collection, data statistical analysis, interpretation of results, manuscript writing, and final manuscript editing. Amanda Tavares da Silva, Anne Silva Martins, and Natália Arruda contributed to data collection, interpretation of results, and final manuscript editing.

Acknowledgments

The authors thank the Study and Research Group in Plant Production Science (GEPFi) the Seed Laboratory (LASEM) of the State University of Goiás for their support in implementing and conducting the experiments, and the State University of Goiás (UEG) for the financial support (Pro-Programs call Nº. 21/2022) for this study project.

Bibliographic References

Baraich, A.A.K., Gandahi, A.W., Tunio, S., Chachar, Q., 2016. Influence of micronutrients and their method of application on yield and yield components of sunflower. Pakistan Journal of Botany, 48(5), 1925-1932. http://pakbs.org/pjbot/PDFs/48(5)/19.pdf (acessado 14 de novembro de 2018).

Bonacin, G.A., Rodrigues, T.J.D., Cruz, M.C.P., Banzatto, D.A., 2009. Características morfofisiológicas de sementes e produção de girassol em função de boro no solo. Revista Brasileira de Engenharia Agrícola e Ambiental, 13(2), 111–116. DOI: https://doi.org/10.1590/S1415-43662009000200001.

Braz, M.R.S., Rossetto, C.A.V. 2009. Estabelecimento de plântulas e desempenho de plantas em resposta ao vigor dos aquênios de girassol. Ciência Rural, 39(7), 1997-2003. DOI: https://doi.org/10.1590/S0103-84782009000700007.

BRASIL/MAPA. MINISTÉRIO DA AGRICULTURA, PECUÁRIA E ABASTECIMENTO. 2009. Regras para análise de sementes. Secretaria de Defesa Agropecuária. Brasília, 01, 399. https://ainfo.cnptia.embrapa.br/digital/bitstream/CPAMN-2009-09/18068/1/CT154.pdf (acessado 13 de novembro de 2018).

Caldeira, C.M., Carvalho, M.L.M., Oliveira, J.A., Coelho, S.V.B., Kataoka, V.Y. 2014. Vigor de sementes de girassol pela análise computadorizada de plântulas. Científica, 42(4), 346-353. DOI: https://doi.org/10.15361/1984-5529.2014v42n4p346-353.

Carvalho, N.M., Nakagawa, J., 2012. Sementes: ciência, tecnologia e produção. 5.ed. FUNEP: Jaboticabal.

Dias, D.C.F.S., Marcos Filho, J. 1995. Teste de vigor baseados na permeabilidade de membranas celulares: II Lixiviação de potássio. Informativo ABRATES, 5(1), 37-41.

Farinelli, R., Penariol, F.G., Souza, F.S., Piedade, A.R., Lemos, L.B. 2006. Características agronômicas e qualidade fisiológica de sementes de cultivares de feijão adubados via foliar com cálcio e boro. Científica, 34(1), 59-65. DOI: https://doi.org/10.15361/1984-5529.2006v34n1p59%20-%2065.

Freitas, G.Q., Teixeira, M.B., Cabral Filho, F.R., Cunha, F.N., Silva, N.F., Favareto, R., Alves, D.K.M., Soares, F.A.L., Vidal, V.M. 2021. Cultivo do girassol sob diferentes condições de adubação orgânica e mineral. Research, Society and Development, 10(6), e1010615395. DOI: http://dx.doi.org/10.33448/rsd-v10i6.15395.

Guedes, R.S., Alves, E.D., Gonçalves, E.P., Viana, J.S., Medeiros, M.S., Lima, C.R. 2009. Teste de comprimento de plântula na avaliação da qualidade fisiológica de sementes de Erythrina velutina Willd. Semina: Ciências Agrárias, 30(4), 793-802. https://www.redalyc.org/articulo.oa?id=445744094006. (acessado 14 de novembro de 2018).

Haesbaert, F.M., Lopes, S.J., Mertz, L.M.M., Lúcio, A.D., Huth, C., 2017. Tamanho de amostra para determinação da condutividade elétrica individual de sementes de girassol. Bragantia, 76(1), 54-61. DOI: https://doi.org/10.1590/1678-4499.389.

Lima, A.D., Viana, T.V.A., Azevedo, B.M., Marinho, A.B., Duarte, J.M., 2013. Adubação borácica na cultura do girassol. Revista Agro@ambiente On-Line, 7(3), 269-276. DOI: https://doi.org/10.18227/1982-8470ragro.v7i3.1237.

Marchetti, M.E., Motomya, W.R., Fabrício, A.C., Novelino, J.O., 2001. Resposta do girassol, Helianthus annuus, a fontes e níveis de boro. Acta Scientiarum, 23(05), 1107-1110. DOI: https://doi.org/10.4025/actasciagron.v23i0.2566.

Marcos Filho, J., 2005. Fisiologia de sementes de plantas cultivadas. Piracicaba: FEALQ. 495p.

Nakagawa, J., 1999. Testes de vigor baseados no desempenho das plântulas. In: Krzyzanowski, F.C., Vieira, R.D., França Neto, J.B., (Ed.), Vigor de sementes: conceitos e testes. ABRATES, Londrina.

Nunes, R.T.C., Cangussu, A.C.V., Oliveira, C.C., Santos, A.P.S., Morais, O.M., 2016. Qualidade fisiológica de sementes de girassol classificadas pelo tamanho. Agropecuária científica no semiárido, 12(2), 153-161. DOI: http://dx.doi.org/10.30969/acsa.v12i2.728.

Scheeren, B.R., Peske, S.T., Schuch, L.O.B., Barros, A.C.A., 2010. Qualidade fisiológica e produtiva de sementes de soja. Revista Brasileira de Sementes, 32(3), 35-41. DOI: https://doi.org/10.1590/S0101-31222010000300004.

Silva, R.C., Grzybowski, C.R.S., França-Neto, J.B., Panobianco, M., 2013. Adaptação do teste de tetrazólio para avaliação da viabilidade e do vigor de sementes de girassol. Pesquisa Agropecuária Brasileira, 48(1), 105-113. DOI: https://doi.org/10.1590/S0100-204X2013000100014.

Smaniotto, T.D.S., Resende, O., Marçal, K.A., Oliveira, D.D., Simon, G.A., 2014. Qualidade fisiológica das sementes de soja armazenadas em diferentes condições. Revista Brasileira de Engenharia Agrícola e Ambiental, 18(4), 446-453. DOI: https://doi.org/10.1590/S1415-43662014000400013.

Talamini, V.; Almeida, N.A., Lima, N.R.S., Silva, A.M.F., Carvalho, H.W.L., Sousa, R.C. 2011. Avaliação da qualidade física, fisiológica e sanitária de sementes de girassol introduzidas para cultivo em Sergipe. Embrapa Tabuleiros Costeiros. http://www.infoteca.cnptia.embrapa.br/infoteca/handle/doc/1014416 (acessado 12 de novembro de 2018).

Toledo, M.Z., Fonseca, N.R., César, M.L., Soratto, R.P., Cavariani, C., Crusciol, C.A.C., 2009. Qualidade fisiológica e armazenamento de sementes de feijão em função da aplicação tardia de nitrogênio em cobertura. Pesquisa Agropecuária Tropical, 39(2), 124- 133.

Zobiole, L.H.S., Castro, C., Oliveira, F.A., Oliveira Junior, A., 2010. Marcha de absorção de macronutrientes na cultura do girassol. Revista Brasileira de Ciência do Solo, 34(2), 425- 433. DOI: https://doi.org/10.1590/S0100-06832010000200016.

Zonta, E.P., Machado, A.A., Silveira Júnior, P., 1987. Sistemas de análise estatística para microcomputadores: Manual de utilização. 2. ed. UFPEL, Pelotas.

Wissuwa, M., Ismail, A.M., Graham, R.D., 2008. Rice grain zinc concentrations as affected by genotype, native soil-zinc availability, and zinc fertilization. Plant and Soil, 306(1-2), 37-48. DOI: https://doi.org/10.1007/s11104-007-9368-4.