Bulgarian Journal of Agricultural Science, 27 (Suppl. 1) 2021
Agricultural Academy

Screening of temperature tolerance and adaptive potential of *Sorghum vulgare* var. *technicum* [Körn] genotypes

Slaveya Petrova[1,2], Bogdan Nikolov[1], Plamen Marinov-Serafimov[3], Irena Golubinova[3] and Ekaterina Valcheva[4*]

[1]*Plovdiv University "Paisii Hilendarski", Faculty of Biology, Department of Ecology and Environmental Conservation, 4000 Plovdiv, Bulgaria*
[2]*Agricultural University, Faculty of Plant Protection and Agroecology, Department of Microbiology and Ecological Biotechnologies, 4000 Plovdiv, Bulgaria*
[3]*Instute of Forage Crops, 5800 Pleven, Bulgaria*
[4]*Agricultural University, Faculty of Plant Protection and Agroecology, Department of Agroecology and Environmental Protection, 4000 Plovdiv, Bulgaria*
[*]*Corresponding author:* katia_valcheva@abv.bg

Abstract

Petrova, S., Nikolov, B., Marinov-Serafimov, Pl., Golubinova, I. & Valcheva, E. (2021). Screening of temperature tolerance and adaptive potential of *Sorghum vulgare* var. *technicum* [Körn] genotypes. *Bulg. J. Agric. Sci., 27 (Suppl. 1)*, 119–124

Rising temperatures are proving detrimental for various agricultural crops. There is a need for heat tolerant crops with high adaptation capacity to the climate changes as an alternative of traditional cultivars. The objective of this study was to evaluate the effect of wide temperature range (10, 20 and 30°C) on water absorption capacity and seed germination of several *Sorghum vulgare* var. *technicum* Körn. genotypes. Based on the dynamics of seed imbibition observed, regardless of the temperature, the studied genotypes could be arranged into an increasing row as follows: G16V < GL16A < Szegedi 1023 < Mi16N < S14 < Prima = CR16LR < PL16. Peak values of water absorption by all tested seeds are found between 2nd and 6th hour at 10°C and 20°C, as well as between 2nd and 4th hour at 30°C ($p<0.05$). Significant relationships were observed depending on genotype reaction and differentiation under the temperature influence ($P \geq 0.05$). Seed germination at 10°C was found only at two of studied seven genotypes – GL16A (9.6%) and MI16N (38.0%). These two local populations of *Sorghum vulgare* var. *technicum* Körn. (GL16A and MI16N genotypes) demonstrated high germination rates at 10-30°C range and could be used as potential donors of thermotolerance toward low and high temperatures in a breeding program.

Keywords: climate change; water absorption; seed imbibition; germination; broom corn

Introduction

Water absorption is an essential part of the seed germination process and is influenced by various environmental factors – temperature, humidity, osmotic pressure and others (Kader & Jutzi, 2002). Adverse abiotic environmental factors (high temperatures, prolonged drought, high soil pH, etc.), especially during the germination process, lead to the poor crop development. In such conditions take place mainly thermophilic technical crops (such as sorghum) with increased adaptability, high productive and allelopathic potential, tolerant to biotic and abiotic stresses.

Water absorption capacity of seeds from different crops depends on the type and size of seeds, temperature, permeability of the seed coat, oxygen uptake, storage and others (de Pinho et al., 2004; Azam-Ali et al., 2006). Seed germination is defined as a series of metabolic and morphological processes that transform the embryo into a germ, also being influenced by abiotic environmental factors (Dehnavi et al., 2020). The temperature range directly affects seed germination and can have an inhibitory or stimulating effect (Krenchinski et al., 2015).

As a species of the genus *Sorghum*, *Sorghum vulgare* var. *technicum* [Körn.] has a high ecological plasticity and slope in extreme droughts, which is a prerequisite for the formation of aboveground biomass during the summer depressions of perennial forage cereal grasses. Technical sorghum (broom corn) is a crop with different applications (fodder, seeds, as well as in compaction of crop rotations). It is grown in a wide area, with minimal tillage, which requires the identification of tolerant genotypes towards a wide temperature range during seed germination and initial plant development (Singh, 1985; Bacon et al., 1986). Many authors have shown that stress factors in the critical period of development of species of the genus *Sorghum* – "sowing-germination", revealed to yields reduction (Pirasteh-Anosheh et al., 2011; Hamidi et al., 2013).

The aim of the present study is to evaluate the effect of a wide temperature range on the water absorption capacity and germination of seeds from eight accessions (genotypes) of *Sorghum vulgare* var. *technicum* [Körn.] with different origin.

Materials and Methods

The study was conducted under laboratory conditions at the Institute of Forage Crops – Pleven, in 2019-2020. Eight specimens of the species *Sorghum vulgare* var. *technicum* [Körn.], with different origin, were included in the screening process (Table 1). The experimental work was performed in two stages: 1) Effect of temperature (10, 20 and 30°C) on water absorption capacity of seeds (% Ws); Effect of temperature (10, 20 and 30°C) on seed germination.

Table 1. Description of specimens (genotypes) of *Sorghum vulgare* var. *technicum* (Körn.)

№	Name	Variety/ Population	Origin
1	Szegedi 1023	Variety	Hungary
2	Prima	Variety	Serbia
3	S14	Local population	Southeast Bulgaria
4	GL16A	Local population	Central Northern Bulgaria
5	PL16	Local population	Central Northern Bulgaria
6	CR16LR	Local population	Central Northern Bulgaria
7	G16V	Local population	Central Northern Bulgaria
8	Mi16N	Local population	Central Northern Bulgaria

Air-dried seeds from each genotype were pre-cleaned of impurities and manually calibrated. A number of 500 seeds per specimen, pre-sterilized with 1.0% NaOCl and washed twice with distilled water, have been placed in plastic containers (50 ml capacity). Distilled water (30 ml) was added into containers and they were placed in a thermostat at 10, 20 and 30°C ± 2°C temperature for 24 hours. Each variant was set in five replications.

The water absorption capacity of seeds (%Ws, g absorbed H_2O per g seeds) was determined by weight change on the 2nd, 4th, 6th, 8th, 10th, 12th and 24th hours. The formula of Hidayati et al. (2001) was used for calculations:

$$\%Ws = \frac{Wi - Wd}{Wd} \times 100,$$

where: *Wi* – mass of seeds (g) on 2nd, 4th, 6th, 8th, 10th, 12th and 24th hour, respectively;

Wd – mass of air-dried seeds, (g).

The water absorption rate of seeds (R, g absorbed H_2O per hour) on the 2nd, 4th, 6th, 8th, 10th, 12th and 24th hours respectively, was calculated according to formula of Mamonov & Kim (1978):

$$R = \frac{W2 - W1}{t2 - t1},$$

where: *W*1 – mass of air-dried seeds (g);

*W*2 – mass of seeds (g) on 2nd, 4th, 6th, 8th, 10th, 12th and 24th hour, respectively;

*t*2 – *t*1 – duration of soaking the seeds in distilled water.

After 24 hours, 25 seeds of each sample were placed in petri dishes (9 mm diameter) between filter paper (Filtrak, 383) and 2 ml of distilled water was pipetted. Each variant was set in five replications. The petri dishes were incubated in a thermostat at 10°C, 20°C and 30°C ± 2°C temperature for a 3-day period. Seed germination (%) was observed according to Shekoofa et al. (2020).

Raw data were processed by mathematical and statistical analyses using the software product STATGRAPHICS Plus for Windows Version 2.1. The differences between the seeds water absorption capacity have been tested according to the converted Fisher criterion (Plohinskii, 1967).

Results and Discussion

The water absorption capacity of seeds (% Ws) from studied genotypes of *Sorghum vulgare* var. *technicum* depends mainly on the temperature and on the duration of exposure, and to a lesser extent – on their biological characteristics (Table 2).

Table 2. Dynamics of water absorption capacity (% Ws) of *Sorghum vulgare* var. *technicum* [Körn.] seeds

Genotypes	t,°C	tφ	Imbibition time, h							Correlations (r)
			2	4	6	8	10	12	24	
			Water absorption capacity, %Ws							
Szegedi 1023	10°C		9.18	13.05	17.26	19.58	21.57	22.57	28.87	0.891
		tφ/10°C	0.005	0.321	1.090	1.639	2.205	2.473	4.609	
	20°C		10.39	15.36	19.56	22.21	24.42	26.08	35.03	0.914
		tφ/20°C	0.017	0.705	1.629	2.356	3.357	3.564	7.115	
	30°C		14.94	20.56	25.39	28.43	30.79	32.25	41.01	0.875
		tφ/30°C	1.088	1.903	3.357	4.421	5.345	5.955	9.981	
Prima	10°C		11.31	15.09	18.21	20.80	22.95	24.03	31.25	0.890
		tφ/10°C	0.375	1.124	1.936	2.666	3.475	3.834	6.802	
	20°C		14.16	19.68	24.65	27.35	29.62	30.92	41.51	0.895
		tφ/20°C	0.919	2.383	4.092	5.141	6.056	6.623	11.869	
	30°C		16.13	22.84	28.25	29.98	31.49	32.58	42.53	0.858
		tφ/30°C	1.369	3.404	5.510	6.230	6.892	7.393	12.485	
S14	10°C		9.66	12.50	16.25	19.77	22.27	24.32	29.66	0.899
		tφ/10°C	0.164	0.577	1.419	2.414	3.230	3.943	6.099	
	20°C		11.65	16.29	21.04	23.64	25.90	27.94	37.33	0.913
		tφ/20°C	0.439	1.419	2.796	3.689	4.548	5.345	9.679	
	30°C		17.22	23.00	27.56	30.11	32.00	33.89	43.67	0.868
		tφ/30°C	1.657	3.475	5.222	6.274	7.117	8.002	13.177	
GL16A	10°C		9.66	13.87	16.54	17.31	17.98	18.53	27.97	0.901
		tφ/10°C	0.164	0.855	1.471	1.683	1.879	2.022	5.385	
	20°C		12.94	17.59	22.35	24.23	25.77	27.21	38.83	0.912
		tφ/20°C	0.672	1.766	3.265	3.906	4.509	5.060	10.459	
	30°C		16.21	21.83	26.46	28.89	30.65	32.19	43.00	0.881
		tφ/30°C	1.394	3.061	4.781	5.761	6.535	7.202	12.770	
PL16	10°C		10.10	13.92	17.40	20.76	23.68	26.49	31.76	0.899
		tφ/10°C	0.225	0.884	1.753	2.718	3.785	4.851	7.110	
	20°C		10.84	14.30	19.22	23.24	25.70	29.05	39.78	0.899
		tφ/20°C	0.319	0.972	2.277	3.605	4.537	5.922	11.151	
	30°C		13.13	19.35	23.80	27.14	30.03	33.04	44.61	0.943
		tφ/30°C	0.698	2.339	3.823	5.051	6.309	7.666	13.826	
CR16LR	10°C		9.59	15.01	18.85	20.77	22.46	24.04	30.14	0.924
		tφ/10°C	0.166	1.158	2.187	2.718	3.357	3.896	6.353	
	20°C		12.97	17.52	22.18	25.48	27.76	29.47	39.48	0.878
		tφ/20°C	0.698	1.781	3.255	4.460	5.376	6.529	10.935	
	30°C		16.86	22.74	28.28	30.66	32.35	33.82	42.42	0.908
		tφ/30°C	1.616	3.428	5.584	6.617	7.341	8.525	12.541	
G16V	10°C		10.53	13.71	17.11	18.53	19.74	20.83	29.93	0.851
		tφ/10°C	0.277	0.842	1.698	2.183	2.432	2.718	6.266	
	20°C		12.43	17.23	21.59	23.56	25.19	26.72	38.39	0.911
		tφ/20°C	0.583	1.698	3.049	3.750	4.345	4.930	10.351	
	30°C		14.05	19.06	22.66	25.05	26.91	28.65	40.52	0.918
		tφ/30°C	0.906	2.247	3.428	4.269	5.012	5.751	11.478	
Mi16N	10°C		9.10	11.98	13.94	17.40	19.70	21.77	28.80	0.912
		tφ/10°C	0.105	0.489	0.855	1.711	2.383	3.061	5.717	
	20°C		12.73	16.90	19.79	22.22	24.07	25.69	36.34	0.928

Table 2. Continued

		tφ/20°C	0.612	1.576	2.414	3.198	3.868	3.868	9.222	
	30°C		15.86	20.92	26.09	28.97	31.72	33.33	41.95	0.915
		tφ/30°C	1.318	2.763	4.619	5.803	6.982	7.919	12.203	

Legend: The statistical evaluation of seeds water absorption capacity was performed trough the converted Fishers test "tφ" by the "φ" method at the t criterion ($P_{0.05\%}$≥2.06), ($P_{0.01\%}$≥2.79) and ($P_{0.001\%}$≥3.73)

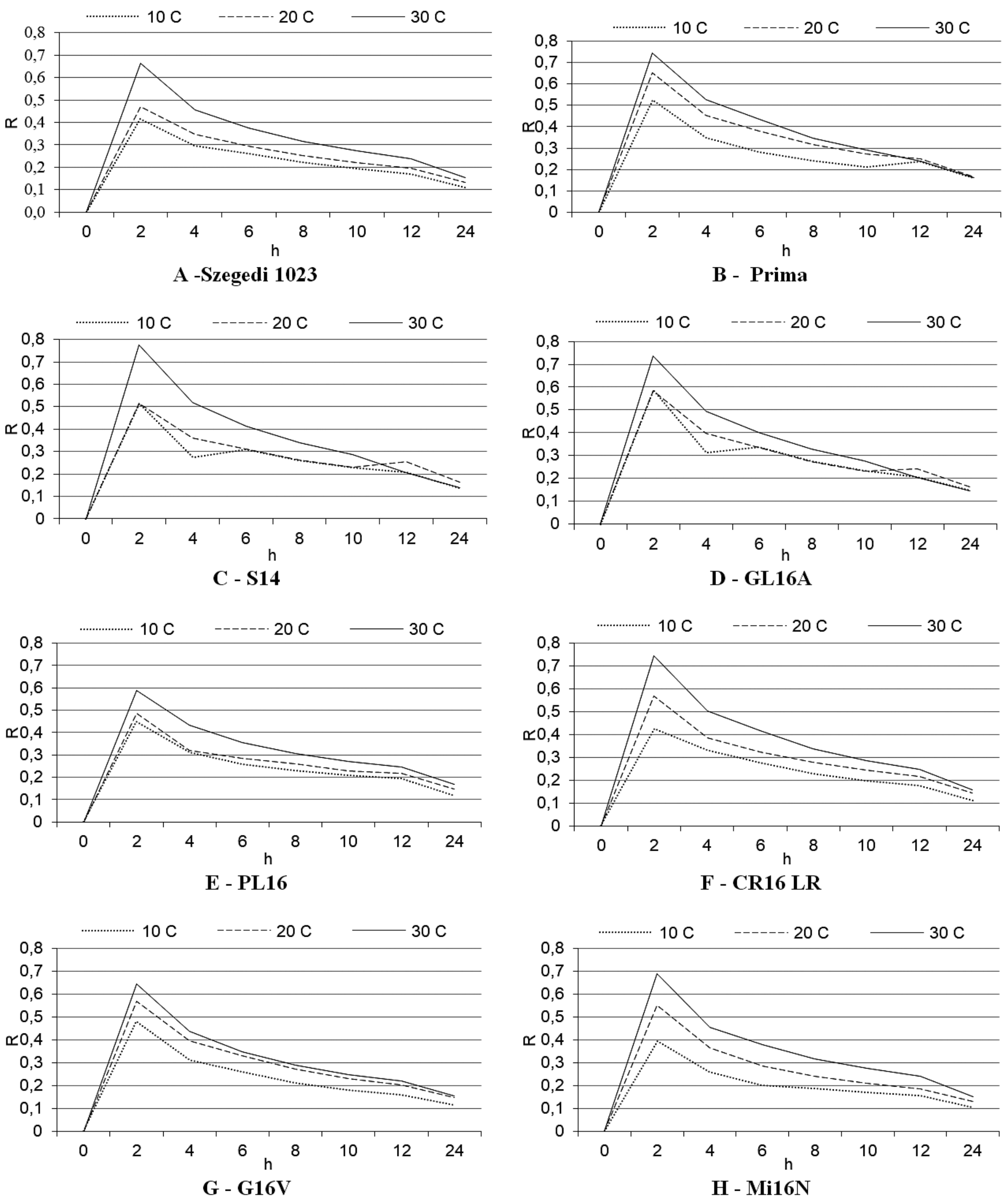

Fig. 1. Water absorption rate of seeds (R–g/ H_2O/h) in all experimental variants

Minimum water absorption capacity of the seeds from all studied sorghum genotypes was observed at 10°C – Ws% is from 9.18 to 10.53% at the 2nd hour. The water absorption capacity (Ws%) increases from 10.39% to 14.16% and from 13.11% to 17.22% at 20°C and 30°C, respectively, for the same time period.

Significant dynamics in the water absorption capacity of the seeds from the tested genotypes was proven ($p<0.05$). The maximum water absorption is reached at 24th hour, when the seeds at 10°C absorbed from 27.9 to 31.8% of their initial weight, at 20°C – from 35.5 to 41.5%, and at 30°C – from 40.5 to 44.6% (Figure 1). Similar results were published by Li et al. (2019), which found that the increasing temperature increases the water absorption capacity and germination of seeds.

Peak values in the water absorption of all seeds are found between 2nd and 6th hours at 10 and 20°C, while at 30°C these values are between 2nd and 4th hours. As the duration of water absorption increases from 8 to 12 hours, the water absorption capacity of the seeds decreases, but the total amount of water absorbed increases.

The relatively higher water absorption capacity of the seeds in the initial hours (2nd – 6th h) is probably due to the intensive physico-chemical phase of the water absorption process. Generally, the water absorption in the tested seeds could be divided in three stages: 1) up to 6th h – the water is adsorbed relatively quickly; 2) between 8th and 12th h – water absorption decreases and reaches almost its full volume; 3) up to 24th h – complete hydration of the seeds. The differences between three stages are statistically proven by φ – Fisher's test (Table 2).

According to the summarized data of Andrejko & Kamińska (2005), some exothermic intensive reactions take place in the process of water absorption of seeds from different crops in the initial hours (3rd – 5th h), and slow down after. Similar results have been reported by Golubinova & Vasilevska-Ivanova (2008) in some *Sorghum* species.

According to their water absorption capacity (regardless of the temperature), the seeds of studied genotypes, could be arranged in the following ascending order: G16V < GL16A < Szegedi 1023 < Mi16N < S14 <Prima = CR16LR < PL16.

The highest water absorption capacity at 24th hour and in whole applied temperature range (10-30°C) was found for the seeds from local population PL16, which is defined as a suitable acceptor in allelopathic studies. The water absorption capacity of Prima variety, local populations CR16LR and G16V in the temperature range 20-30°C is relatively similar. It was found that at 24th h the amount of absorbed water from the seeds in relation to the mass of air-dried seeds is 1:0.5.

Similar results were obtained by monitoring the course of the curves expressing the rate of water absorption (R– g absorbed H_2O/h) of seeds (from 2nd to 24th h) at different temperature (10, 20 and 30°C) (Figure 1). The highest rate of water absorption of seeds is through the physico-chemical phase from 2nd to 8th hour, after that it decreases and stops at the 24th hour, no matter of the exposure temperature.

The germination of seeds depending on their water absorption capacity and applied temperatures varies in a wide range from 30.0 to 95.0% (Table 3). Significant relationships were observed depending on genotype reaction and differentiation under the temperature influence ($p<0.05$). Seed germination at 10°C was found only at two of studied seven genotypes – GL15A (9.6%) and MI16N (38.0%). The highest percentage of germinated seeds (85.0-95.0%) was reported at the highest test temperature – 30°C, and it decrease up to the range of 30 to 80% with the temperature fall down. Similar results were obtained in the experimental work of Razmi et al. (2014). According to the authors, despite the fact that *Sorghum bicolor* L. originates from the semi-arid tropics, genotypes tolerant to temperature stress have been established.

The results of dispersion and correlation analyze evaluating the influence and relationships of the studied factors (temperature (A) and genotype (B)) on the seed germination

Table 3. Germination percentage of studied genotypes of *Sorghum vulgare* var. *technicum* [Körn.]

Genotypes	Temperature, °C			
	10	20	30	Average
Szegedi 1023	0.0a	80.0e	87.0ab	55.7b
Prima	0.0a	48.0bc	85.0a	44.3ab
S14	0.0a	58.0cd	93.0bc	50.3ab
GL16A	9.6b	30.0a	88.0ab	41.0a
PL16	0.0a	55.0cd	95.0c	50.0ab
CR16LR	0.0a	60.0d	88.0ab	49.3ab
G16V	0.0a	38.0ab	93.0bc	43.7ab
Mi16N	38.0c	60.0d	92.0bc	63.3c

Legend: Means with different a ,b, c and d at P=0.05 level of probability by LSD test

Table 4. Analysis of variance and degree of influence of the factors on the germination of seeds

Causes of variation	Degrees of freedom	Sum of squares	Mean square	Influence of factors (η^2)
Factor A – Temperatures, °C	2	6576.2	3288.11	93.29
Factor B – Genotypes	7	110.63	15.8005	1.57
Interaction A×B	14	233.52	16.6798	3.31
Error	96	128.80	1.34167	1.83
Total	119	7049.17		

revealed that the largest part of the total variation is due to Factor A (temperature) (93.29%). High correlations were found when determining the seed germination as a function of temperature (r varies from 0.851 to 0.943). Insignificant in the total variation is the share of Factor B (genotype) – 1.57% (Table 4).

Conclusions

According to the dynamics of water absorption, regardless of the temperature (10-30°C), the studied genotypes of technical sorghum (*Sorghum vulgare* var. *technicum* [Körn.]) can be arranged in the following order: G16V < GL16A < Szegedi 1023 < Mi16N < S14 < Prima = CR16LR < PL16.

Maximum of the water absorption rate of all studied seeds was observed between 2^{nd} and 6^{th} h at 10 and 20°C, while at 30°C it was between the 2^{nd} and 4^{th} h.

A specific genotypic reaction and differentiation depending on temperature (10, 20 and 30°C) were established. Seed germination at 10°C was reported only in local populations GL16A and MI16N – 9.6 and 38.0%, respectively.

Local populations GL16A and Mi16N of *Sorghum vulgare* var. *technicum* are suitable donors in breeding programs, such as donors of tolerance to high and low temperatures.

References

Andrejko, D. & Kamińska, A. (2005). Selected properties of yellow lupine seeds formed by hydration. EJPAU *8*(4), #82. Available Online: http://www.ejpau.media.pl/volume8/issue4/art-82.html

Azam-Ali, S., Bonkoungou, E., Bowe, C., de Kock, C., Godara, A. & Williams, J. (2006). Ber and other jujubes. In: Williams et al. (Eds.), International Centre for Underutilized Crops, Southampton, UK.

Bacon, R., Cantrell, R. & Axtell, J. (1986). Selection for seedling cold tolerance in grain sorghum. *Crop Science, 26(5),* 900–903.

Dehnavi, Ah., Zahedi, M., Ludwiczak, A., Perez, S. & Piernik, A. (2020). Effect of salinity on seed germination and seedling development of sorghum (*Sorghum bicolor* (L.) Moench) genotypes. *Agronomy*, *10(6),* 859 https://doi.org/10.3390/agronomy10060859.

de Pinho, S., de Carvalho, L. & Delachiave, M. (2004). Limit between stages I and II of a seed imbibition curve. *Scientia Agricola (Piracicaba, Braz.), 61(1),* 17-20.

Golubinova, I. & Vasilevska-Ivanova, R. (2008). Temperature effect on seed imbibition in *Sorghum*. *Comptes rendus de l, Academie Bulgare des Sciences*, *61(11),* 1491-1496.

Hamidi, R., Pirasteh-Anosheh, H. & Izadi, M. (2013). Effect of seed halo-priming compared with hydro-priming on wheat germination and growth. *International Journal of Agronomy and Plant Production, 4(7),* 1611-1615.

Hidayati, S., Baskin, J. & Baskin, C. (2001). Dormancy-breaking and germination requirements for seeds of *Sympforicarpos orbiculatus* (*Carifoliaceae*). *American Journal of Botany*, *88(8),* 1444-1451.

Kader, M. & Jutzi, S. (2002). Temperature, osmotic pressure and seed treatments influence imbibition rates in sorghum seeds. *Journal of Agronomy and Crop Science*, *188(4),* 286-290.

Krenchinski, F., Albrecht, A., Albrecht, L., Villetti, H., Orso, G., Barroso, A. & Victoria Filho, R. (2015). Germination and Dormancy in Seeds of *Sorghum halepense* and *Sorghum arundinaceum*. *Planta Daninha*, *33(2),* 223-230.

Li, M., Eyre, J., Broad, I. & Rodriguez, D. (2019). Sorghum (*Sorghum bicolour* L.) Germination Dynamics at Extreme Temperatures. *Proceedings*, *36(1),* 40 https://doi.org/10.3390/proceedings2019036040.

Mamonov, L. & Kim, G. (1978). Mathematical modeling of physiological processes in plants. ANK Botany Institute, *Publishing House "Nauka"* Alma-Ata (Ru).

Pirasteh-Anosheh, H, Sadeghi, H. & Emam Y. (2011). Chemical priming with urea and KNO_3 enhances maize hybrids (*Zea mays* L.) seed viability under abiotic stress. *Journal of Crop Science and Biotechnology, 14(4),* 289-295.

Plohinskii, N. (1967). Algorithms of Biometry. Publishing House of the Moscow University, 74-78 (Ru).

Singh, S. P. (1985). Sources of cold tolerance in grain sorghum. *Canadian Journal of Plant Science*, *65(2),* 251-257.

Shekoofa, A., Safikhan, S., Raper, T. & Butler, S. (2020). Allelopathic impacts of cover crop species andtermination timing on cotton germination and seedling growth. *Agronomy*, *10(5),* 638-647. doi:10.3390/agronomy10050638.

Received: May, 19, 2021; *Accepted:* June, 25, 2021; *Published:* September, 2021