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Effects of drought stress in genotypes *Sorghum vulgare* var. *technicum* [Körn.] by using sucrose in laboratory condition

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Abstract

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The effect of sucrose on the induction of water stress on germination and the initial development of five genotypes (varieties and local populations) *Sorghum vulgare* var. technicum [Körn.] was determined under laboratory conditions at the Institute of Forage Crops, Pleven. In order to simulate the water deficit induced by osmotic stress, different concentrations (0.08%; 0.16%; 0.32%; 0.64%; 1.25%; 2.5%; 5.0%; 7.5%; 10.0%; 12.5%; 15.0%; 17.5% and 20.0%) of water soluble sucrose were used in the study.

It was found a specific variety reaction with regard to the effect of different sucrose concentration on seedling growth (cm) and fresh weight of seedlings (g) in the tested genotypes *Sorghum vulgare* var. *technicum* (Körn.). With low coefficients of tolerance, i.e. the high sensitivity of drought conditionally, can be determined the genotypes Szegedi 1023 and AS17P (STI is from 2.9 to 4.6). Genotypes GL15A, G16V and MI16N showed better performance in drought conditions in the early drought stages of development (BBCH 09-10) (STI average varied from 2.1 to 3.9). Due to their drought tolerance properties these genotypes will be used in future breeding program for producing drought tolerant genotypes.

Keywords: Sorghum vulgare var. *technicum*; drought stress; sucrose

Introduction

Plant growth and productivity is affected by many biotic and abiotic factors (Al-Rifaee et al., 2007; Tawaha & Al-Ghzawi, 2013; Barłóg et al., 2016; Bazitov et al., 2016; Bozhinova, 2016; Shafea & Saffari, 2016; Al-Tawaha et al., 2017). Drought stress is the most prevalent environmental factor limiting crop productivity (Bray, 1997), and global climate change is increasing the frequency of severe drought conditions (Dai, 2012). Plant abiotic stresses such as drought stress threaten global food availability as the increase in world population and per capita food consumption (Qadir et al., 2015). Drought severely affects plant growth and development with substantial reductions in crop growth rate and biomass accumulation (Farooq et al., 2012). Drought disrupts major metabolic, physiological and biochemical processes (Pustovoitova et al., 1996; Chaves et al., 2003). It is very important to understand the physiological, biochemical, and ecological interventions related to these stresses for better management of agroecosystems (Fahad et al., 2017). Drought tolerance is important trait related to yield. To improve this trait, breeding requires fundamental changes in the set of relevant attributes, finally emerging as something named drought tolerance (Maleki et al., 2013). A better understanding of plant responses to these stresses gives an opportunity to determine specific response and tolerance to drought in early growth stages of development in a number of agricultural crops (Alexieva et al., 2003; Borrell et al., 2014; Tsago et al., 2014). Plant response to drought stress generally varies from species to species depending on plant growth stage and other environmental factors (Demirevska et al., 2009).

Sorghum species are a multiuse crop grown for feed, food and with a huge potential for bioenergy. It can be cultivated in numerous environments due to its wider adaptation property (Bazitov and Kikindonov, 2016). As compared to other cereal crops *Sorghum* species considered to be more tolerant to different stresses including drought, heat, flooding and salinity (Ejeta and Knoll, 2007; Ali et al., 2011; Bazitov et al., 2017). The crop requires relatively less water than other important cereals such as maize and wheat. Yield potential of the *Sorghum* species is requiring relatively less water than other important cereals such as maize and wheat. However, yield potential of the crop is significantly limited due to drought and heat stresses necessitating sorghum breeding for drought tolerance and productivity (Krupa et al., 2017). There are a number of physiological indicators of tolerance that show genotypic variation especially at the vegetative stage of growth, for drought resistance (Alhamdani et al., 1991). For that reason, evaluating germplasm from different region of Bulgaria can be useful in discovering tolerant genotypes for drought resistance in the early growth stages.

Materials and Methods

The experiment was conducted under laboratory conditions at the Institute of Forage Crops, Pleven.

Plant materials: The experiment was carried out with five broomcorn genotypes (*Sorghum vulgare* var. *technicum* (Körn.) with different origin from work collection in Institute of forage crops, Pleven (Table 1). In order to establish the influence of water deficit at the initial growth stages and development were used adapted method Chaniago et al. (2017).

Table 1. Genotypes broomcorn *(Sorghum vulgare* var. technicum)

№	Genotypes	Methods of creation	Country
1.	Szegedi 1023	Variety	Hungary
2.	AS17P	Local population	Bulgaria
3.	GL15A	Local population	Bulgaria
4.	G16V	Local population	Bulgaria
5.	MI16N	Local population	Bulgaria

Two factors have been studied: Factor A – genotypes of *Sorghum vulgare* var. *technicum* (Körn.) (broomcorn), and Factor B – sucrose concentrations.

Factor A: a_1 – Szegedi 1023 (Hungarian variety); local varieties from the region of Central Northern Bulgaria: a_2 – AS17P; a_3 – GL15A; a_4 – G16V; a_5 – MI16N.

Factor B: b_1 – 0.0% (control); b_2 – 0.08%; b_3 – 0.16%; b_4 – 0.32%; b_5 – 0.64%; b_6 – 1.25%; b_7 – 2.5%; b_8 – 5.0%; b_9 – 7.5%; b_{10} – 10.0%; b_{11} – 12.5%; b_{12} – 15.0% b_{13} – 17.5% and b_{14} – 20.0%.

Technique of bioassay: Two hundred seeds from tested genotypes broomcorn were germinated on two layers of filter paper Filtrak 388 in Petri dishes with diameter 140 mm and distilled water at a ratio of 1:2.5 to the mass of the seeds. The prepared samples were placed in an incubator at 48 h at 23°C ± 2°C. Seeds were considered as germinated if they exhibited radicle extension by more than ≥ 3.0 mm.

Successively, twenty germinated seeds of each genotypes *Sorghum vulgare* var. *technicum* (Körn.) (according Factor A) were placed between filter paper Filtrak 388, in the Petri dishes for all tested concentrations sucrose. From all concentrations of sucrose (Factor B) in the petri dishes, 5 ml of solution was pipetted. The prepared samples were placed in an incubator at 22 ± 2°C in the dark for five days. Each treatment consisted of six replicates, including the control treatment.

Effect assessment: For assessing experimental results, the following characteristics were determined:

Biometric parameters: root, shoot and seedling length, cm; fresh biomass weight per seedling, g. Length was measured using graph paper and weight on an analytical balance. Mathematical-statistical evaluation and calculated formulas:

Inhibition rate (IR) was determined by the equation (1) (Ahn et al., 2005):

$$IR\% = [(C - T)/C].100 \quad (1)$$

where C – characteristic in the control treatment; T – characteristics in each treatment. Positive values "+" show inhibition effect, while negative "–" values show stimulation effect.

Stress tolerance index was determined by the equation (2) (Fernandez, 1992):

$$STI = \frac{Y_P * Y_S}{\bar{Y}_P^2} \quad (2)$$

where Y_S is the parameter of cultivar under stress, Y_P – the parameter of cultivar under irrigated condition, $\bar{Y}_P^2$ is the mean parameter of all variants under stress conditions.

The estimates obtained by application of the program product TRIMED SPEARMAN KARBER METOD, VERSION 1.5 were used to determine effective median lethal concentration, LC50 (abbreviation for "lethal concentration, 50%") for inhibition of germination and 95% confidence intervals for different sucrose extracts in genotypes *Sorghum vulgare* var. *tehnicum* were calculated according to Hamilton et al. (1978).

Statistical analyses: Statistical processing of the experimental data was conducted after preliminary transformation of the percentage of germinated seeds using the following formula:

$$Y = \arcsin\sqrt{\left(\frac{x\%}{100}\right)} \text{ (Hinkelmann \& Kempthorne, 1994).}$$

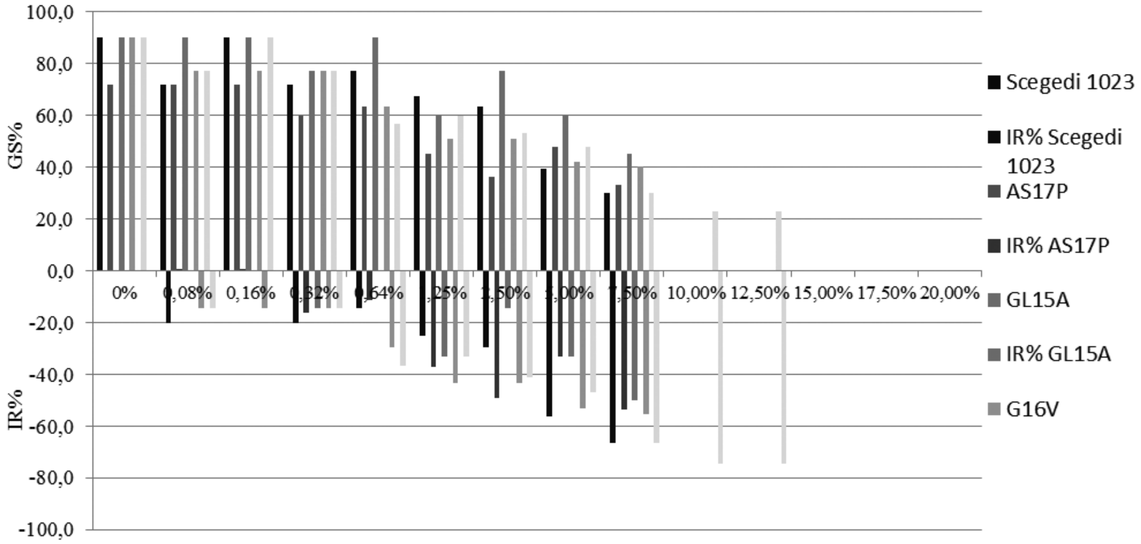
All experimental data were statistically processed using the software STATGRAPHICS Plus for Windows Version 2.1.

Results and Discussion

The applied sucrose concentrations (from 0.0 to 20.0%) have an inhibiting effect on seed germination in all genotypes *broomcorn* (*Sorghum vulgare* var. technicum (Körn.)). The results of Fig. 1 showed that the germination of seeds on broomcorn was reduced with the increase in sucrose concentrations. The degree of reduction in rate of germination was not similar for all tested genotypes at moderate and higher water deficit stress compared to control treatments. The highest germination percentage was observed at the lower (0.08÷0.64%) sucrose concentrations ($GS_{\%}$ from 63.4 to 90.0%) with the lower degree of inhibition ($IR_{\%}$ is from 0.0 to 16.2%), and the differences from the control treatment ($GS_{\%}$ 64.8%) are not significant (P = 0.05). It was found that the seeds germinated more often under mild stress (at the 1.25 and 2.50% sucrose) for all tested *broomcorn* genotypes than compared to relatively higher concentration from 5.0% the differences being statistically significant (P = 0.05) compared to the control treatment. A statistically significant decline (at P = 0.05) in the germination percentage was recorded at 7.5%, indicating this sucrose concentration is a threshold value for the germination seeds of broomcorn. The germination percentage at the 10.0, 12.5, 15.0, 17.5 and 20.0% sucrose concentrations had lethal effect on germination of seeds for tested *broomcorn* genotypes. Therefore, at the 7.5% sucrose concentration, there is the highest osmotic potential for germinations of seeds of *broomcorn*.

As shown in Fig. 1, an increase sucrose concentration of the were found to reduce seed germination of all tested *broomcorn genotypes*, and the $IR_{\%}$ values increased from 0.31 to 85.0% compared with the lowest applied concentration of sucrose. An exception to the described dependence was found in the local population MI16N. There are not germinated seeds at the 15.0% sucrose concentration, which indicated that 12.5% sucrose concentration is the highest osmotic potential for the germination local population MI16N, which determines it as relatively resistant to drought during the early growth stage BBCH 09-10.

The data were analogous when determining LC_{50} according degree of inhibition (IR) depending to seed germination at tested broomcorn genotypes. The LC_{50} values for the tested broomcorn genotypes varied from 1.96 to 3.93% sucrose



LSD at the 0.05 probability level	A	B	AxB
$GD_{5\%}$	4.07	6.81	5.46
$GD_{1\%}$	5.38	9.00	7.91
$GD_{0.1\%}$	6.93	11.59	10.59

Fig. 1. Germination in genotypes broomcorn *(Sorghum vulgare* var. *technicum)*

concentrations and could be conventionally grouped in the following ascending order: AS17P [1.96 (1.69-2.27)] > Szegedi 1023 [2.73 (2.39-3.13)] > G16V [3.40 (2.61-4.43)] > GL15A [3.95 (3.52-4.44)] > MI16N [3.95 (3.08-5.01)]. The differences in the LC_{50} values form broomcorn genotypes could be explained by genetic differences with genetic differences, as comparisons were made under controlled laboratory conditions (Fig. 2).

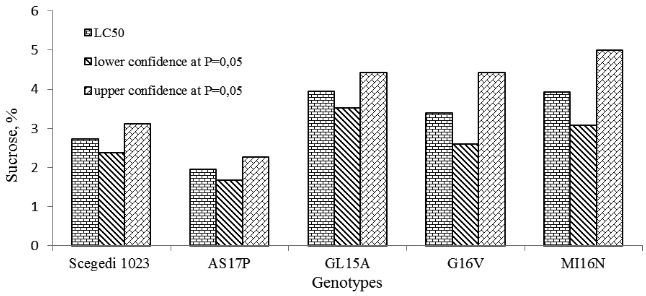


Fig. 2. Values of lethal dose (LD 50) in different genotypes broomcorn *Sorghum vulgare* var. *technicum*

The extracts from different concentration of sucrose inhibited growth of root, shoot and seedlings of all broomcorn genotypes (Tables 2 and 3). Differences in the root, shoot and seedling values under different level of drought are indicator for the level of drought tolerance. The present study revealed differences in plant performance between the different characteristics of the tested genotypes broomcorn.

The effect of drought stress induced by sucrose on the seedling length (cm) on the tested broomcorn genotypes is presented in Table 2. Length of shoot in all genotypes of broomcorn vary at rates between 0.00% and 95.31%, compared to the control treatment, the differences being statistically proven at P = 0.01.

Shoot length decreased as the concentrations of sucrose increased and the greatest inhibition was observed at the 7.5% ($IR_{\%}$ is from 90.88 to 95.61%) (Table 2). The inhibition rate (IR) is 100.00% in the highest concentrations of sucrose (from 10.0 to 20.0%). In the local variety MI16H inhibition rate ($IR_{\%}$) reached 100.0% at a sucrose concentration of 12.5%. An exception was found for GL15A in which 0.64% sucrose concentrations indicated a statistically proven stimulating effect on shoot and seedling growth. In the genotype MI16N a lethal effect was found at a higher sucrose concentration of 12.5%.

The growth of root, shoot and seedling indicated that all genotypes broomcorn in early growth stage (BBCH 09-10) after treatments the seeds with sucrose concentrations in the diapason from 1.25 to 7.5% suffered significant physiological stress despite the proven drought resistance of the tested genotypes. There was a specific reaction in different varieties with regard to the effect of sucrose concentrations on the growth on seedling. Seedlings length at broom corn local variety GL15A was increases intensively (from 13.38 to 15.75 cm) when exposed sucrose concentration in diapason from 0.08 to 0.64% and formed the longest seedling after treatment, compared to the control treatment (13.34 cm).

Relatively long seedling was formed in local varieties G16V (from 12.56 to 16.64 cm), MI16N (from 10.75 to 16.53 cm) and Szegedi 1023 (from 13.18 to 16.36 cm) while values of the control treatments are as follows G16V (14.78 cm), MI16N (15.30 cm) and Szegedi 1023 (14.32 cm). Seedlings length at the local variety AS17P was significantly different to other local varieties and ranges from 9.06 to 13.10 cm, compared to the control treatments (12.50 cm). Therefore, depending on the intensity of the growth of the seedlings, only the local variety AS17P can be identified as susceptible to drought stress.

Therefore, the observed differences in the studied genotypes when the growth of the seedlings from broomcorn with regard to the osmotic stress after application sucrose of sucrose could be explained by genetic differences, because experiment was performed under controlled laboratory conditions. Reducing fresh biomass of root, shoot and seedling is common the response of crop plants when subjected to moisture deficiency (Munamava & Riddoch, 2001; Gill et al., 2003; Ambika et al., 2011).

The dynamics of accumulation of fresh biomass (shoot, root and seedling) in the early stages of the growth of tested broomcorn genotypes depends on genotypes, applied sucrose concentration and observed dependence on seedlings length (Table 3). The drought stress induced by the application of sucrose had a depressing effect (IR% is from 16.7 to 59.1) on the formed fresh biomass of the root, shoot and seedlings at the tested genotypes broomcorn. With increasing concentrations (from 0,32 to 7.5%) of sucrose the suppressive effect on the growth of the seedlings increased from 1.2 to 1.8 times as the differences were statistically significant (P = 0.05).

In the broomcorn genotypes GL15A and MI16N with the increasing concentration of sucrose (from 2.5 to 12.5%) accumulation of fresh biomass (g for one seedling) remains relatively constant compared to the control treatments and the differences are statistically insignificant (P = 0.05) which can be explained by their tolerance to drought in the early growth stages of development (BBCH 09-10) (Table 4).

A high negative correlation was detected between applied sucrose concentration and: germination of seeds (*r* from -0.923 to -0.948), length of the root (*r* from -0.805 to -0.937), length of the shoot (*r* of -0.820 to -0.870), length

Table 2. Growth of seedlings in genotypes broomcorn (*Sorghum vulgare* var. *technicum*) under different concentrations of sucrose

Geno-types	Parameters	Concentrations. %													
		0.0	0.08	0.16	0.32	0.64	1.25	2.50	5.00	7.50	10.00	12.50	15.00	17.50	20.00
Szegedi 1023	Shoot, cm	6.82cd	7.78d	6.00c	6.00c	6.50c	1.88b	0.83ab	0.65ab	0.50ab	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		-14.08	12.02	12.02	4.69	72.43	87.83	90.47	92.67	100.00	100.00	100.00	100.00	100.00
	STI		9.87	7.61	7.61	8.25	2.39	1.05	0.82	0.63	0.00	0.00	0.00	0.00	0.00
	Root, cm	7.50de	8.58e	7.40de	6.17c	6.68cd	3.56b	2.97b	0.54a	0.24a	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		-14.40	1.33	17.73	10.93	52.53	60.40	92.80	96.80	100.00	100.00	100.00	100.00	100.00
	STI		8.33	7.18	5.99	6.48	3.45	2.88	0.52	0.23	0.00	0.00	0.00	0.00	0.00
	Seedlings	14.32e	16.36f	13.55de	12.17de	13.18de	5.44c	3.79bc	1.19ab	0.44a	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		-14.25	5.38	15.01	7.96	62.01	73.53	91.69	96.93	100.00	100.00	100.00	100.00	100.00
	STI		9.06	7.50	6.74	7.30	3.01	2.10	0.66	0.24	0.00	0.00	0.00	0.00	0.00
AS17P	Shoot, cm	6.25d	6.90d	6.31d	6.32d	4.38c	1.44b	0.84ab	1.05ab	0.57ab	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		-10.40	-0.96	-1.12	29.92	76.96	86.56	83.20	90.88	100.00	100.00	100.00	100.00	100.00
	STI		9.42	8.62	8.63	5.98	1.97	1.15	1.43	0.78	0.00	0.00	0.00	0.00	0.00
	Root, cm	6.25e	6.20e	6.61e	6.64e	4.69d	3.25cd	2.53bc	1.5b	1.67b	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		0.80	-5.76	-6.24	24.96	48.00	59.52	76.00	73.28	100.00	100.00	100.00	100.00	100.00
	STI		5.98	6.38	6.41	4.52	3.14	2.44	1.45	1.61	0.00	0.00	0.00	0.00	0.00
	Seedlings	12.50d	13.10d	12.92d	12.96d	9.06c	4.69b	3.37b	2.55b	2.23ab	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		-4.80	-3.36	-3.68	27.52	62.48	73.04	79.60	82.16	100.00	100.00	100.00	100.00	100.00
	STI	1.17	7.47	7.36	7.39	5.16	2.67	1.92	1.45	1.27	0.00	0.00	0.00	0.00	0.00
GL15A	Shoot, cm	6.66cd	6.95cd	7.40d	6.24cd	5.90c	1.90b	1.84b	1.11ab	0.40a	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		-4.35	-11.11	6.31	11.41	71.47	72.37	83.33	93.99	100.00	100.00	100.00	100.00	100.00
	STI		7.76	8.27	6.97	6.59	2.12	2.06	1.24	0.45	0.00	0.00	0.00	0.00	0.00
	Root, cm	6.68 e	7.30ef	8.35f	7.86f	7.48ef	5.23d	3.21c	2.05bc	1.31ab	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		-9.28	-25.00	-17.66	-11.98	21.71	51.95	69.31	80.39	100.00	100.00	100.00	100.00	100.00
	STI		4.50	5.15	4.85	4.61	3.22	1.98	1.26	0.81	0.00	0.00	0.00	0.00	0.00
	Seedlings	13.34e	14.25ef	15.75f	14.11ef	13.38ef	7.13cd	5.04cd	3.16bc	1.71ab	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		-6.82	-18.07	-5.77	-0.30	46.55	62.22	76.31	87.18	100.00	100.00	100.00	100.00	100.00
	STI		5.78	6.39	5.73	5.43	2.89	2.05	1.28	0.69	0.00	0.00	0.00	0.00	0.00
G16V	Shoot, cm	7.61ef	8.04f	6.34de	6.28de	5.88d	2.73c	2.38bc	0.94ab	0.40a	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		-5.65	16.69	17.48	22.73	64.13	68.73	87.65	94.74	100.00	100.00	100.00	100.00	100.00
	STI		9.50	7.49	7.42	6.95	3.23	2.81	1.11	0.47	0.00	0.00	0.00	0.00	0.00
	Root, cm	7.13d	8.61e	7.79de	7.40de	6.69d	4.96c	4.08bc	2.98b	1.50a	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		-20.76	-9.26	-3.79	6.17	30.43	42.78	58.20	78.96	100.00	100.00	100.00	100.00	100.00
	STI		5.36	4.85	4.60	4.16	3.09	2.54	1.85	0.93	0.00	0.00	0.00	0.00	0.00
	Seedlings	14.74ef	16.64f	14.13def	13.68de	12.56d	7.69c	6.47bc	3.92b	1.90a	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		-12.89	4.14	7.19	14.79	47.83	56.11	73.41	87.11	100.00	100.00	100.00	100.00	100.00
	STI		6.99	5.94	5.75	5.28	3.23	2.72	1.65	0.80	0.00	0.00	0.00	0.00	0.00
MI16N	Shoot, cm	7.74cd	7.79cd	6.25c	5.68bc	5.75bc	2.60b	0.43a	0.51a	0.34a	0.27a	0.27a	0.00a	0.00a	0.00a
	IR%		-0.65	19.25	26.61	25.71	66.41	94.44	93.41	95.61	96.51	96.51	100.00	100.00	100.00
	STI		11.41	9.15	8.32	8.42	3.81	0.63	0.75	0.50	0.40	0.40	0.00	0.00	0.00
	Root, cm	7.55cd	8.74d	7.30cd	5.84c	5.00c	5.17c	1.94b	1.70b	1.20ab	0.73ab	0.70ab	0.00a	0.00a	0.00a
	IR%		-15.76	3.31	22.65	33.77	31.52	74.30	77.48	84.11	90.33	90.73	100.00	100.00	100.00
	STI		7.59	6.34	5.07	4.34	4.49	1.69	1.48	1.04	0.63	0.61	0.00	0.00	0.00
	Seedlings	15.30d	16.53d	13.55cd	11.53cd	10.75c	7.77b	2.38a	2.22a	1.54a	1.00a	0.97a	0.00a	0.00a	0.00a
	IR%		-8.04	11.44	24.64	29.74	49.22	84.44	85.49	89.93	93.46	91.05	100.00	100.00	100.00
	STI		9.07	7.44	6.33	5.90	4.26	1.31	1.22	0.85	0.55	0.75	0.00	0.00	0.00

Table 3. Fresh weight of seedlings in broomcorn (*Sorghum vulgare* var. *technicum*) genotypes under different concentrations of sucrose

Genotypes	Param-	Concentrations. %													
	eters	0.0	0.08	0.16	0.32	0.64	1.25	2.50	5.00	7.50	10.00	12.50	15.00	17.50	20.00
Szegedi 1023	Shoot, cm	0.031c	0.021b	0.021b	0.020b	0.022b	0.020b	0.020b	0.023b	0.022b	0.000a	0.000a	0.000a	0.000a	0.000a
	IR%		32.26	32.26	35.48	29.03	35.48	35.48	25.81	29.03	100.00	100.00	100.00	100.00	100.00
	STI		3.85	3.85	3.67	4.04	3.67	3.67	4.22	4.04	0.00	0.00	0.00	0.00	0.00
	Root, cm	0.038e	0.029d	0.022c	0.021c	0.021c	0.020c	0.020c	0.010b	0.010b	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		23.68	42.11	44.74	44.74	47.37	47.37	73.68	73.68	100.00	100.00	100.00	100.00	100.00
	STI		7.96	6.04	5.76	5.76	5.49	5.49	2.74	2.74	0.00	0.00	0.00	0.00	0.00
	Seedlings	0.069d	0.050cd	0.043c	0.040c	0.043c	0.039c	0.039c	0.030b	0.030b	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		27.54	37.68	42.03	37.68	43.48	43.48	56.52	56.52	100.00	100.00	100.00	100.00	100.00
	STI		5.91	5.09	4.73	5.09	4.61	4.61	3.55	3.55	0.00	0.00	0.00	0.00	0.00
AS17P	Shoot, cm	0.035c	0.025b	0.025b	0.020b	0.020b	0.022b	0.026b	0.024b	0.024b	0.00a	0.00a	0.00a	0.000a	0.000a
	IR%		28.57	28.57	42.86	42.86	37.14	25.71	31.43	31.43	100.00	100.00	100.00	100.00	100.00
	STI		4.27	4.27	3.42	3.42	3.76	4.45	4.10	4.10	0.00	0.00	0.00	0.00	0.00
	Root, cm	0.048d	0.047d	0.047d	0.033c	0.032c	0.015b	0.013b	0.009ab	0.007ab	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		2.08	2.08	31.25	33.33	68.75	72.92	81.25	85.42	100.00	100.00	100.00	100.00	100.00
	STI		9.25	9.25	6.50	6.30	2.95	2.56	1.77	1.38	0.00	0.00	0.00	0.00	0.00
	Seedlings	0.083d	0.071c	0.071c	0.053c	0.052c	0.039bc	0.038bc	0.033b	0.03b	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		14.46	14.46	36.14	37.35	53.01	54.22	60.24	63.86	100.00	100.00	100.00	100.00	100.00
	STI		6.65	6.65	4.96	4.87	3.65	3.56	3.09	2.81	0.00	0.00	0.00	0.00	0.00
GL15A	Shoot, cm	0.033c	0.024bc	0.028bc	0.022b	0.022b	0.028bc	0.028bc	0.032bc	0.028bc	0.00a	0.00a	0.00a	0.000a	0.000a
	IR%		27.27	15.15	33.33	33.33	15.15	15.15	3.03	15.15	100.00	100.00	100.00	100.00	100.00
	STI		2.98	3.47	2.73	2.73	3.47	3.47	3.97	3.47	0.00	0.00	0.00	0.00	0.00
	Root, cm	0.036d	0.037d	0.040d	0.042d	0.035d	0.029cd	0.020bc	0.011b	0.010b	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		-2.78	-11.11	-16.67	2.78	19.44	44.44	69.44	72.22	100.00	100.00	100.00	100.00	100.00
	STI		4.49	4.85	5.09	4.24	3.52	2.43	1.33	1.21	0.00	0.00	0.00	0.00	0.00
	Seedlings	0.068e	0.061de	0.068e	0.064de	0.057cde	0.058cde	0.048bcd	0.043bc	0.038b	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		10.29	0.00	5.88	16.18	14.71	29.41	36.76	44.12	100.00	100.00	100.00	100.00	100.00
	STI		3.67	4.09	3.85	3.43	3.49	2.89	2.59	2.29	0.00	0.00	0.00	0.00	0.00
G16V	Shoot, cm	0.034d	0.020bc	0.023bc	0.022bc	0.018b	0.020bc	0.026c	0.026c	0.023bc	0.00a	0.00a	0.00a	0.000a	0.000a
	IR%		41.18	32.35	35.29	47.06	41.18	23.53	23.53	32.35	100.00	100.00	100.00	100.00	100.00
	STI		3.63	4.17	3.99	3.26	3.63	4.72	4.72	4.17	0.00	0.00	0.00	0.00	0.00
	Root. cm	0.032d	0.030d	0.020bc	0.020bc	0.028d	0.026cd	0.019bc	0.018b	0.016b	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		6.25	37.50	37.50	12.50	18.75	40.63	43.75	50.00	100.00	100.00	100.00	100.00	100.00
	STI		5.18	3.45	3.45	4.83	4.49	3.28	3.11	2.76	0.00	0.00	0.00	0.00	0.00
	Seedlings	0.066c	0.050bc	0.043b	0.042b	0.046b	0.046b	0.045b	0.044b	0.039b	0.00a	0.00a	0.00a	0.00a	0.00a
	IR%		24.24	34.85	36.36	30.30	30.30	31.82	33.33	40.91	100.00	100.00	100.00	100.00	100.00
	STI		4.43	3.81	3.72	4.07	4.07	3.98	3.89	3.45	0.00	0.00	0.00	0.00	0.00
MI16N	Shoot, cm	0.034c	0.033c	0.028bc	0.030bc	0.027bc	0.032c	0.026b	0.030bc	0.022b	0.030bc	0.027b	0.00a	0.000a	0.000a
	IR%		2.94	20.59	11.76	20.59	2.94	-20.59	11.76	-5.88	-17.65	20.59	100.00	100.00	100.00
	STI		1.81	1.48	1.64	1.48	1.81	2.24	1.64	1.97	2.19	1.48	0.00	0.00	0.00
	Root, cm	0.032e	0.034e	0.025d	0.022d	0.025d	0.021d	0.020d	0.012c	0.008bc	0.005ab	0.00a	0.00a	0.00a	0.00a
	IR%		-6.25	21.88	31.25	21.88	15.63	56.25	62.50	75.00	90.63	100.00	100.00	100.00	100.00
	STI		6.36	4.68	4.12	4.68	5.05	2.62	2.25	1.50	0.56	0.00	0.00	0.00	0.00
	Seedlings	0.066ef	0.067f	0.053def	0.052def	0.052def	0.053def	0.046de	0.042cde	0.044bc	0.035bcd	0.027b	0.00a	0.00a	0.00a
	IR%		-1.52	21.21	21.21	21.21	9.09	16.67	36.36	33.33	34.85	59.09	100.00	100.00	100.00
	STI		3.06	2.38	2.38	2.38	2.74	2.51	1.92	2.01	1.97	1.23	0.00	0.00	0.00

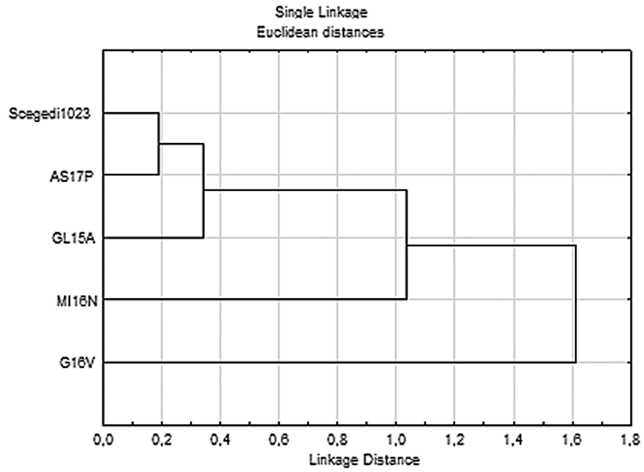


Fig. 3. A dendrogram from cluster analysis based on the quantitative parameters in genotypes broomcorn *(Sorghum vulgare* var. *technicum)*

of the seedling (*r* of -0.901 to -0.947), fresh biomass (g) per root (*r* from -0.806 to -0.917), fresh biomass (g) per shoot (*r* of -0.838 to -0.877) and fresh biomass (g) per seedling (*r* of -0.900 to -0.941) for the genotypes of broomcorn.

The quantitative changes in the parameters correspond to the defined stress tolerance index (STI) (Table 2 and 3). The genotypes GL15A, G16V and MI16N are with relatively good tolerance to drought stress which is possible to determine (STI average varied from 2.1 to 3.9). With high coefficients of STI, i.e. the high sensitivity of drought in the early growth stages of development (BBCH 09-10) were the Szegedi 1023 and AS17P genotypes (STI varied from 2.9 to 4.6) (Table 2 and 3).

On the basis of the values of the analyzed quantitative signs, hierarchical cluster analysis was performed for grouping the genotypes of a technical broom as the result of the analysis is presented as dendrograms (Fig. 2). The Euclidean distance is used as a measure of distance.

The genotypes GL15A, G16V and MI16N stand out with the best combination of a set of quantitative signs. The cluster analysis provides significant additional information and can be used to schedule parent parenting combinations in breeding programs. The most remote genotypes may be useful for creating starting material.

Dispersion analysis was made to determine the hierarchical distribution of factors determining osmotic stress on the tested broomcorn genotypes induced by the addition of different concentration of sucrose (Table 4). Dispersion analysis was hewed that Factor A (genotypes) (η^2 varied from 0.1 to 0.4) and interaction AxB (η^2 from 1.0

Table 4. Main effects of the factors tested

Indicators	Causes of variation	Intercept	Factor A - genotypes	Factor B - concentration	Interaction A x B	Error	Total
Root length	Sum of squares	6926.20	22.20	11169.41	165.28	4899.57	17369.5
	Mean square	6926.201	5.550	859.185	3.178	4.195	
	Influence of factors, η^2		0.1	64.3	1.0		
Shoot lenght	Sum of squares	10239.47	81.12	11895.21	362.02	4311.87	18065.1
	Mean square	10239.47	20.28	915.02	6.96	3.69	
	Influence of factors, η^2		0.4	65.8	2.0		
Seedling length	Sum of squares	34008.54	183.78	45657.68	850.24	14488.88	66179.7
	Mean square	34008.54	45.94	3512.13	16.35	12.40	
	Influence of factors, η^2		0.3	69.0	1.3		
Root weight	Sum of squares	0.044068	0.000425	0.002031	0.004932	0.002998	0.010388
	Mean square	0.044068	0.000106	0.000226	0.00022	0.000013	
	Influence of factors, η^2		54.5	11.3	31.1		
Shoot weight	Sum of squares	1.465138	3.930919	0.853953	2.377129	0.230057	7.392058
	Mean square	1.465138	0.982730	0.065689	0.045714	0.001643	
	Influence of factors, η^2		53.2	11.6	32.2		
Seedling weight	Sum of squares	0.224495	0.002643	0.119490	0.011136	0.009540	0.142810
	Mean square	0.224495	0.000661	0.009192	0.000214	0.000068	
	Influence of factors, η^2		1.9	83.7	7.8		

Legend: LSD at the 0.05 probability level to 1.3) were within the limits but Factor B (sucrose concentration) (η^2 from 64.3 to 69.0) had the strongest statistically significant (P = 0.05) effect for the root, shoot and seedlings length. Regarding weight parameters root, shoot and seedlings weight, Factor A (genotypes) had to a statistical significance (η^2 from 1.9 to 54.5), followed by Factor B (sucrose concentration) (η^2 from 11.3 to 83.7). Interaction of the genotypes (Factor A) and applied concentration (Factor B) had a relatively high proportion of total variation of η^2 from 7.8 to 32.2 and had statistical significance regarding formed fresh biomass of root, shoot and seedlings.

Conclusion

The drought tolerance in five genotypes *Sorghum vulgare* var. *technicum* (Körn.) in the early growth stages and development BBCH 09-10 was evaluated through artificially created water stress by sucrose in laboratory conditions. There was a specific variety reaction with regard to the effect of different sucrose concentration on seedling growth (cm) and fresh weight of seedlings (g) in the tested genotypes *Sorghum vulgare* var. *technicum* (Körn.). The germination percentage at the 10.0, 12.5, 15.0, 17.5 and 20.0% sucrose concentrations had lethal effect on germination of seeds for tested *broomcorn* genotypes.

It is found a high negative correlation between applied sucrose concentration and: germination of seeds (*r* from -0.923 to -0.948), length of the root (*r* from -0.805 to -0.937), length of the shoot (*r* of -0.820 to -0.870), length of the seedling (*r* of -0.901 to -0.947), fresh biomass (g) per root (*r* from -0.806 to -0.917), fresh biomass (g) per shoot (*r* of -0.838 to -0.877) and fresh biomass (g) per seedling (*r* of -0.900 to -0.941) in the *Sorghum vulgare* var. *technicum* (Körn.) genotypes.

The LC50 values for the *Sorghum vulgare* var. *technicum* (Körn.) genotypes varied from 1.96 to 3.93% sucrose concentrations and could be conventionally grouped in the following ascending order: AS17P [1.96 (1.69-2.27)] > Szegedi 1023 [2.73 (2.39-3.13)] > G16V [3.40 (2.61-4.43)] > GL15A [3.95 (3.52-4.44)] > MI16N [3.95 (3.08-5.01)].

With low coefficients of tolerance, i.e. the high sensitivity of drought conditionally can be determined the Szegedi 1023 and AS17P genotypes (STI average varied from 2.9 to 4.6). Genotypes GL15A, G16V and MI16N showed better performance in drought conditions in the early drought stages of development (BBCH 09-10) (STI average varied from 2.1 to 3.9). Due to their drought tolerance properties these genotypes will be used in future breeding program for producing drought tolerant genotypes.

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