ECOLOGIA BALKANICA
2020, Vol. 12, Issue 1 June 2020 pp. 11-19

Effect of Cycocel 750 SL on Germination and Initial Development of Some Sorghum Species

Irena A. Golubinova[1*], Bogdan N. Nikolov[2], Slaveya T. Petrova[2,3], Iliana G. Velcheva[2], Ekaterina G. Valcheva[3], Plamen A. Marinov-Serafimov[1]

1 - Instute of Forage Crops, Scientific Department of Breeding and Seed Production of Forage Crops, 89 Gen. Vladimir Vazov Street. 89, Pleven, 5800, BULGARIA
2 - Plovdiv University "Paisii Hilendarski", Faculty of Biology, Department of Ecology and Environmental Conservation, 24 Tzar Asen Street, Plovdiv, 4000, BULGARIA
3 - Agricultural University, Faculty of Agroecology and Plant Protection, Department of Agroecology and Environmental Protection, 2 Mendeleev Blvd., Plovdiv, 4000, BULGARIA
[*]Corresponding author: golubinova@abv.bg

Abstract. During the period 2018-2019, a laboratory test was carried out to determine the effect of Cycocel 750 SL (750 g/l chlormequat chloride) on germination and initial development of selected samples of *Sorghum* species: *Sorghum bicolor* L., *Sorghum sudanense* (Piper.) Stapf. and *Sorghum vulgare* var. *technicum* Körn. Cycocel 750 SL is usually applied as plant growth regulator with retardant activity on wheat (*Triticum* sp.) but some authors have observed a stimulatory effect on germination and root elongation of many crops when it was applied for pre-sowing treatment of seeds. We found, that the combined application of Cycocel 750 SL (as pre-sowing treatment and foliar application) in concentrations 0.75-3.8% w/v leads to the enhanced germination of seeds as well as to the significant decrease of shoot-to-root ratio (expressed by the Coefficient of allometry, CA) in all experimental variants in comparison with the control one. Shoot development was significantly inhibited in all cases while the root growth was depressed only at lower concentration applied (0.75% w/v) and stimulated by higher doses of Cycocel (1.5-3.8% w/v). Seedling vigor index (SVI) revealed 24-48% higher values after the Cycocel 750 SL application on *S. vulgare* var. *technicum* (2.6% w/v), *S. bicolor* (2.6% w/v) and *S. sudanense* (3.0% w/v).

Key words: hormo-priming, germination rate, plant growth regulators, crops.

Introduction

Sorghum is the fifth most produced grain globally (Mundia et al., 2019). High ecological plasticity and increased resistance to various abiotic stress factors (atmospheric and soil drought) determine *Sorghum* spp. as promising crops for inclusion in crop rotation under conditions of global warming and drought (House, 1985; Moyer et al., 2003; Berenji & Dahlberg, 2004; Angelova et al., 2011; Stefaniak et al., 2012). At present, *Sorghum sudanense* (Piper.) Stapf. hybrids are preferred as a fodder due to higher yields and sibling ratios and also their thin stems and higher leaf ratios (Uzun et al., 2009). *Sorghum bicolor* (L.) Moench find various applications as human food, animal feed, industry raw material, biofuel production,

Union of Scientists in Bulgaria – Plovdiv
University of Plovdiv Publishing House

etc. (Bibi & Ali, 2012; Serna-Saldívar et al., 2012; Cifuentes et al., 2014). *Sorghum vulgare* var. *technicum* Körn. is mainly utilized for producing brooms, washing brushes, knitting, paper, wallboard, fences, biodegradable materials for packaging due to their peculiar resistance (Popescu & Condei, 2014).

According to the studies of Jamshidi et al. (2011), Fromme et al. (2012), Silva et al. (2014), the exploration of the biological potential of *Sorghum* species, including *S. bicolor*, *S. sudanense* and *S. vulgare* var. *technicum*, is closely linked to overcoming biologically delayed seed emergence and the slow growth rate in the initial stages of their development. This leads to their high sensibility against weed infestation in the first 30-40 days after sawing (Marinov-Serafimov & Golubinova, 2015).

In recent years, research has focused on increasing the viability and germination of seeds in a variety of crops using various chemical and physical methods (Afzal et al., 2006; Lutts et al., 2016; Zheng et al., 2016). The pre-sowing treatment of the seeds aims to increase and synchronize the germination as well as to increase the resistance of the sprouts to abiotic stress. Some authors (Pourmohammad et al., 2013; Singh et al., 2017) find that pre-sowing priming of seeds with growth regulators (with retardant activity) has a stimulating effect on seed germination in a number of crops.

Cycocel is among the most reliable and widely used plant growth regulators with retardant activity on the market today. Cycocel may be used on any crop in the greenhouse or nursery including but not limited to, poinsettias, hibiscus, azaleas, and geraniums to reduce stem elongation, induce early flowering, improve flowering, and to produce compact plants with multiple buds per shoots. In wheat and oats Cycocel 750 stimulates root development, reduces stem length and causes the stem wall to thicken. Primary tiller development is slowed down and secondary tiller development is stimulated (BASF Fact Sheet, 2018).

In their experimental work some authors (Afria et al., 1998; Pirasteh-Anosheh et al., 2016; Singh et al., 2017) found that Cycocel 750 SL could be applied not only on the seedlings but also for priming of seeds. They revealed that the pre-sowing treatment of *Brassica napus* L., *Cyamopsis tetragonoloba* L., *Lens culinaris* Mediec., *Triticum aestivum* L. and *Zea mays* L. had a stimulatory effect on both the germination process and the initial development of plant roots. Similar results have been reported by Ismaeil et al. (1993) which proved that the priming of Sudan grass seeds (*S. sudanense*) with chlormequat chloride decreased the stress effects in plants (inhibition of germination and growing rate) when sowing on saline soils.

Limited studies on the influence of pre-sowing treatment of seeds of some important *Sorghum* crops determines the necessity of such studies in order to establish the effect of priming the seeds as a means of reducing abiotic stress in the germination and initial development of the plants. Aim of the present study was to assess the effect of Cycocel 750 SL (750 g/l chlormequat chloride) on germination and initial development of selected samples of *Sorghum* species: *S. bicolor* (L.) Moench, *S. sudanense* (Piper.) Stapf. and *S. vulgare* var. *technicum* Körn.

Material and methods

Experimental design. Experiment was conducted at laboratory conditions during the period 2018-2019 in the Plovdiv University. Seeds of *S. bicolor* (L.) Moench (1641 hybrid), *S. sudanense* (Piper.) Stapf. (300/43 mutant form) and *S. vulgare* var. *technicum* Körn. (MI 16 N local population from NW Bulgaria) were provided from the Selection Collection of the Institute of Forage Crops in Pleven, Bulgaria.

Number of 108 seeds per species was put into 2.0% NaClO solution for 10 minutes for surface sterilization and then three times thoroughly rinsed with distilled water. After that, the seeds were primed for 24 hours with Cycocel 750 SL (750 g/l chlormequat chloride) at concentrations 0.0 (control), 0.75, 1.5, 2.6, 3.0 and 3.8% w/v following the adapted method of Pourmohammad et al. (2013).

Ex-situ experiment was carried in 0.3 l pots containing a potting mixture of soil, sand and perlite (1:1:1) (Lau et al., 2008). Three seeds per each species and per each test concentration were placed in a pot and left at 22 ± 2°C with 12:12 hours light and dark phase period. All experimental variants were conducted in six replications.

Second application of Cycocel 750 SL was made seven days after seed germination in the phase of the first leaf of the cultures. The treatment with tested growth regulator was carried out by pulverization on the aboveground biomass in all experimental variants at same concentrations as used for seed priming (0.0 (control), 0.75, 1.5, 2.6, 3.0 and 3.8% w/v). Then seedlings were left for another period of seven days at 22 ± 2°C with 12:12 hours light and dark phase. The adapted method of Pourmohammad et al. (2013) was used to assess the effect of Cycocel 750 SL on seed germination and initial development of *Sorghum* crops.

Effect assessment. For evaluation of the experimental results obtained, the following parameters were used: 1. Quantitative parameters - percentage of germination in each treatment (%); 2. Biometric parameters: shoot, root and seedling length (cm) and fresh biomass per plant (g). Length was measured using graph paper and weight - on an analytical balance: 3. Qualitative parameters (calculated by formulas) and statistical processing as described below.

Germination of seeds (GS) was determined by equation, proposed by ISTA (1985), as follows:

$$GS\% = \frac{Number\ of\ seeds\ germinated}{Total\ number\ of\ seeds\ placed} \times 100, \%$$

Inhibition rate (IR) of Cycocel 750 SL on shoot and root growth in experimental variants in comparison to control was calculated according to the adapted formula of Surendra & Pota (1978):

$$IR = \frac{C - T}{C} \times 100, \%,$$

where: IR is the percentage of inhibition, C – control value (germination, number; length, cm; biomass, g); T – treatment value. Values indicate the inhibitory (+) or stimulatory (-) effects in comparison to control treatments.

Seedling vigor index (SVI) was determined using the equation proposed by Islam et al. (2009):

$$SVI = \frac{S \times G}{100},$$

where: S – seedling length in the treatments and control variant, cm; G – germinated seeds in the treatments and control variant, %.

Coefficient of allometry (CA) was calculated by the formula of Nasr & Mansour (2005):

$$CA = \frac{L_s}{L_r},$$

where: L_s is shoot length and L_r is root length, cm.

The seed germination was calculated after preliminary arcsin-transformation following the formula, Y=arcsin√(x%/100), forwarded by Hinkelmann & Kempthorne (1994). All collected data were analyzed using analysis of variance with means separation based on Fisher's least significant difference test at p<0.05 with the software Statgraphics Plus for Windows Ver. 2.1 (1994) and STATISTICA Ver. 10 (StatSoft Inc., 2010).

Results and Discussion

The pre-sowing treatment of seeds of the tested samples of *Sorghum* species with Cycocel 750 SL has a stimulating effect on seed germination in all tested concentration in comparison with the control variants (Table 1) and the differences were statistically significant at $p<0.05$. The percentage of germination of primed seeds increased from 22.3% up to 44.4% in comparison with the untreated ones and was most pronounced for *S. sudanense* genotype. As a whole, maximum stimulation exerted concentrations in the range 0.75-2.6% w/v while higher doses of Cycocel 750 SL (3.0-3.8% w/v) had lower effect (10.5-14.4% raising). Similar results have been reported by Pirasteh-Anosheh et al. (2016), according to which priming of seeds with Cycocel 750 SL induces a stimulating effect on seed germination in wheat, barley, maize and rapeseed, whereas in sunflower, no primary stimulating effect is detected.

According to the genotype response towards the stimulating effect of Cycocel 750 SL on seed germination, the tested *Sorghum* sp. could be arranged as follows: *S. sudanense* ($IR_{average}$ = -31.02%) > *S. vulgare* var. *technicum*, ($IR_{average}$ = -24.5%) > *S. bicolor* ($IR_{average}$ = -19.12%). Therefore, the priming of *Sorghum* seeds could be used as an effective practice to enhance the germination and to reduce the biologically delayed seed emergence which will increase their competitiveness against weed infestation.

Data from biometric measurements on seedling length make it possible to objectively evaluate differences in the initial stages of plant development depending on the Cycocel 750 SL concentration used (Table 2). Treatment with Cycocel 750 SL exhibit a stimulatory effect on the root elongation mainly in *S. sudanense* seedlings where the Inhibition rate varied in the range from -34.3% to -276.5% ($IR_{average}$ = -99.5%), followed by *S. bicolor* seedlings with an IR values between -16.7% and -126.5% ($IR_{average}$= -76.4%), whereas *S. vulgare* var. *technicum*, seedlings were less influenced – IR was in the range from -5.8% up to -67.7% ($IR_{average}$=-27.7%).

On the other hand, regardless of the applied concentration, Cycocel 750 SL significantly inhibited shoot growth in all studied *Sorghum* species ($p<0.05$). Maximum inhibition of shoot development (from 33.3% to 59.1% in comparison with the control) was reported after the combined treatment with Cycocel 750 SL at a dose of 1.5% w/v in all studied genotypes (Table 2). The reduction of shoot length in the experimental variants may be due to a decrease in both cell division and cell number. Similar results were reported by Child (1984) immediately after the application of Cycocel 750 SL on oil rapeseed. Our data well correspond with the findings obtained through the experimental work of Pirasteh-Anosheh et al. (2014) according to which the seed priming with Cycocel 750 SL is an effective means of increasing the root growth rate by redirecting much of the assimilate to the root, since the shoot-to-ratio in barley increases after application of the growth regulator.

When regarding the seedling development as a whole, it was less reduced in *S. bicolor* L. genotype ($IR_{average}$ = 6.6%), followed by *S. vulgare* var. *technicum* Körn. ($IR_{average}$ = 11.4%) and strongest reduction of seedling length was observed in *S. sudanense*. Some exceptions were found at higher concentrations of Cycocel 750 SL (2.6% and 3.0%) where a stimulatory effect occurred with IR values in the range from -1.2% to -9.8% (*S. bicolor* L.) and -17.7% (*S. sudanense* (Piper.) Stapf.).

Cycocel 750 SL treatment of *Sorghum* seeds and seedlings significantly influenced the dynamics of fresh biomass synthesis in all studied genotypes (Table 3). The accumulation of fresh biomass in shoots, roots and seedlings is quite lower after the combined treatment with lower doses of Cycocel 750 SL when compared to the untreated control plants. Treatment with higher doses leads to significant increment only of the root biomass quantity of experimental plants, more expressed at *S. bicolor* and *S. sudanense* ($p<0.05$). Species specific differences in barley's tolerance towards the same growth regulators were reported also by Bahrami et al. (2014). An exception was found in relation to the variant with 2.6% w/v of growth regulator where the significant stimulatory effect occurred in all

Sorghum seedlings. According to the genotype response towards the inhibitory effect of combined treatment with Cycocel 750 SL on the process of biomass synthesis, the tested *Sorghum* sp. could be arranged as follows: *S. bicolor* ($IR_{average}$ = 4.42%) > *S. vulgare* var. *technicum*, ($IR_{average}$ = 2.98%) > *S. sudanense* ($IR_{average}$ = 2.28%).

Table 1. Effect of growth regulator Cycocel 750 SL on laboratory germination of seeds (GS) from *S. vulgare* var. *technicum, S. bicolor* L. and *S. sudanense* (Piper.) Stapf. *Legend:* Statistically significantly differences a, b, c, d, e - LSD at p<0.05.

Concentration, % w/v	*Sorghum vulgare* var. *technicum* Körn.		*Sorghum bicolor* L.		*Sorghum sudanense* (Piper.) Stapf.	
	GS%	*IR*	GS%	*IR*	GS%	*IR*
0.0	69.7^{ab}	0	73.6^{a}	0	63.4^{a}	0
0.75	92.1^{d}	-32.1	94.5^{c}	-28.4	88.0^{c}	-38.8
1.5	92.1^{d}	-32.1	90.0^{c}	-22.3	87.7^{c}	-38.3
2.6	90.0^{d}	-29.1	90.0^{c}	-22.3	91.5^{d}	-44.4
3.0	81.3^{c}	-16.6	82.5^{b}	-12.1	74.4^{b}	-17.4
3.8	78.5^{a}	-12.6	81.3^{b}	-10.5	73.7^{b}	-16.2

Table 2. Effect of growth regulator Cycocel 750 SL on root, shoot and seedling length of *S. vulgare* var. *technicum* Körn., *S. bicolor* L. and *S. sudanense* (Piper.) Stapf. *Legend:* Statistically significantly differences a, b, c, d, e - LSD at p<0.05.

Species	Parameter	Concentration, % w/v					
		0.0	0.75	1.5	2.6	3.0	3.8
Sorghum vulgare var. *technicum* Körn.	Shoot, cm	21.33^{d}	15.6^{b}	14.2^{a}	16.0^{b}	17.6^{c}	17.8^{c}
	IR		26.9	33.3	25.1	17.5	16.7
	Root, cm	6.4^{b}	5.5^{a}	7.9^{bc}	10.7^{d}	6.8^{b}	7.3^{bc}
	IR		14.5	-23.0	-67.7	-5.8	-14.5
	Seedling, cm	27.7^{d}	21.1^{a}	22.1^{ab}	26.7^{cd}	24.4^{c}	25.1^{c}
	IR		24.0	20.3	3.7	12.1	9.5
Sorghum bicolor L.	Shoot, cm	16.73^{c}	10.5^{b}	9.0^{a}	13.9	10.2^{b}	11.5^{b}
	IR		37.1	46.0	16.7	39.2	31.4
	Root, cm	5.4^{ab}	4.9^{a}	9.2^{c}	10.4^{d}	12.2^{e}	6.3^{ab}
	IR		8.7	-70.4	-92.0	-126.5	-16.7
	Seedling, cm	22.1^{c}	15.5^{a}	18.2^{b}	24.3^{d}	22.4^{c}	17.8^{ab}
	IR		30.1	17.6	-9.8	-1.2	19.7
Sorghum sudanense (Piper.) Stapf.	Shoot, cm	16.8^{e}	10.4^{d}	6.9^{a}	9.0^{b}	10.2^{c}	8.1^{b}
	IR		37.9^{a}	59.1^{d}	46.4^{b}	39.3^{a}	51.8^{c}
	Root, cm	3.7^{a}	3.3^{a}	5.0^{b}	5.6^{c}	13.9^{d}	5.0^{b}
	IR		11.6	-34.3	-52.2	-276.5	-35.1
	Seedling, cm	20.5^{cd}	13.7^{b}	11.8^{a}	14.6^{c}	24.1^{d}	13.1^{b}
	IR		33.2	42.2	28.6	-17.7	36.1

Generally, the values of the Seedling vigor index (SVI) in all experimental variants showed a tendency to increase when increasing the concentration of the applied dose of Cycocel 750 SL up to 3.0% w/v (Table 4). The lowest SVI values were observed in seedlings treated with the lowest (0.75% w/v) and the highest (3.8% w/v) doses of studied growth regulator. Maximum values were achieved under the combined application of Cycocel 750 SL (seed priming and shoot pulverization) with concentration of 2.6% w/v at *S. vulgare* var.

technicum and *S. bicolor* and 3.0% w/v at *S. sudanense*. Stimulatory effect on SVI in these seedlings revealed 24.3%, 34.3% and 48.4% respectively when compared to the control variants ($p<0.05$). This result could be explained by the positive influence of Cycocel 750 SL on seed germination and root growth. Our data correlate with the findings of other authors (Pourmohammad et al., 2013; Pirasteh-Anosheh et al., 2014) that seeds priming with an optimal concentrations of Cycocel 750 SL (species specific doses) reduces the adverse effect of the complex influence of abiotic factors through the germination and initial development of barley, maize and rapeseed. According to the genotype response towards the stimulating effect of Cycocel 750 SL on Seedling vigor index, the tested *Sorghum* sp. could be arranged as follows: *S. vulgare* var. *technicum*, ($IR_{average}$ = -5.74%) > *S. bicolor* ($IR_{average}$ = -4.48%) > *S. sudanense* ($SVI_{average}$ = 2%).

The combined treatment with Cycocel 750 SL led to the significant decrement of the values of Coefficient of allometry (CA) in all experimental seedlings in comparison with the control (Table 4). Because the allometric relationships reveal the existence of underlying biophysical constraints to seedling growth, they are an important means to investigate seed and plants after treatment with chemical and/or biological products. Deviations from the expected relationships may also help to explain how plants partition their resources between competing requirements (Daws et al., 2007). Largest variations have been observed in *S. sudanense* (Piper.) Stapf. genotype (CA=1.4-6.2 times lower values), followed by *S. bicolor* L. genotype (CA=0.8-3.2 times lower values) and less affected was *S. vulgare* var. *technicum* Körn. genotype (CA=1.49-2.85 times lower values). Priming of seeds and shoots pulverization with Cycocel 750 SL at doses between 1.5 and 3.0% w/v had the strongest effect on the CA reduction which was due both to the enhanced root elongation and suppressed shoot development (Table 2). Similar results in the experiments of other authors have been explained by a probable blocking of gibberellin biosynthesis (North et al., 2010) or by an increase in ethylene synthesis (Gianfagna, 1995; Shahrokhi et al., 2011).

Table 3. Effect of growth regulator Cycocel 750 SL on fresh biomass accumulation of *S. vulgare* var. *technicum* Körn., *S. bicolor* L. and *S. sudanense* (Piper.) Stapf. *Legend:* Statistically significantly differences a, b, c, d, e - LSD at $p<0.05$.

Species	Parameter	Concentration, % w/v					
		0.0	0.75	1.5	2.6	3.0	3.8
Sorghum vulgare var. *technicum* Körn.	Shoot, g	0.093^{c}	0.071^{a}	0.073^{a}	0.108^{d}	0.087b	0.101^{d}
	IR		23.7	21.5	-16.1	6.5	-8.6
	Root, g	0.029^{c}	0.012^{a}	0.024^{b}	0.057^{e}	0.028^{c}	0.031^{d}
	IR		58.6	17.2	-96.6	3.4	-6.9
	Seedling, g	0.122^{b}	0.083^{a}	0.097^{a}	0.165^{d}	0.115^{b}	0.132^{c}
	IR		32	20.5	-35.2	5.7	-8.2
Sorghum bicolor L.	Shoot, g	0.141^{d}	0.088^{a}	0.123^{c}	0.156^{e}	0.091^{a}	0.103^{b}
	IR		37.6	12.8	-10.6	35.5	27
	Root, g	0.049^{b}	0.018^{a}	0.122^{e}	0.075^{d}	0.061^{c}	0.071^{d}
	IR		63.3	-149	-53.1	-24.5	-44.9
	Seedling, g	0.190^{d}	0.106^{a}	0.245^{e}	0.231^{e}	0.152^{b}	0.174^{c}
	IR		44.2	-28.9	-21.6	20	8.4
Sorghum sudanense (Piper.) Stapf.	Shoot, g	0.050^{b}	0.013^{a}	0.030^{b}	0.060^{c}	0.061^{c}	0.034^{b}
	IR		74.0	40.0	-20.0	-22.0	32.0
	Root, g	0.012^{a}	0.012^{a}	0.025^{d}	0.021^{c}	0.031^{d}	0.016^{b}
	IR		0.0	-108.3	-75	-158.3	-33.3
	Seedling, g	0.10^{b}	0.025^{a}	0.10^{b}	0.10^{b}	0.10^{b}	0.10^{b}
	IR		59.7	11.3	-30.6	-48.4	19.4

Table 4. Effect of growth regulator Cycocel 750 SL on initial development of *S. vulgare* var. *technicum* Körn., *S. bicolor* L. and *S. sudanense* (Piper.) Stapf. *Legend: SVI* - Seedling vigor index; *CA* - Coefficient of allometry; Statistically significantly differences *a, b, c, d, e - LSD* at p<0.05.

Concentration, % w/v	*Sorghum vulgare* var. *technicum* Körn.		*Sorghum bicolor* L.		*Sorghum sudanense* (Piper.) Stapf.	
	SVI	CA	SVI	CA	SVI	CA
0.0	19.33^{a}	3.33^{c}	16.29^{b}	3.10^{c}	13.0^{c}	4.54^{d}
0.75	19.41^{a}	2.85^{bc}	14.61^{a}	2.14^{bc}	12.1^{b}	3.19^{c}
1.5	20.35^{ab}	1.81^{a}	16.41^{b}	0.98^{a}	10.38^{a}	1.38^{ab}
2.6	24.03^{b}	1.49^{a}	21.87^{d}	1.34^{ab}	13.39^{c}	1.60^{b}
3.0	19.81^{ab}	2.60^{b}	18.48^{c}	0.83^{a}	17.95^{d}	0.73^{a}
3.8	19.70^{ab}	2.42^{b}	14.45^{a}	1.82^{b}	9.60^{a}	1.62^{b}

Conclusions

The seed priming with Cycocel 750 SL in 0.75-3.8% w/v concentrations had a stimulating effect on seed germination of studied *Sorghum* species in comparison with the control (p<0.05). The enhancement of germination process varied from 22.3% up to 44.4% and was most pronounced for *S. sudanense* genotype.

The combined application of Cycocel 750 SL (as pre-sowing treatment and foliar pulverization) in concentrations 0.75-3.8% w/v significantly inhibited shoot growth in all studied *Sorghum* genotypes (p<0.05). Maximum inhibition of shoot development (from 33.3% to 59.1% in comparison with the control) was reported after the combined treatment with Cycocel 750 SL at a dose of 1.5% w/v in all tested species. At the same time, the treatment with this growth regulator exhibit a stimulatory effect on the root elongation most pronounced at *S. sudanense* with 99.5% average enhancement of root length, followed by *S. bicolor* with 76.4%, whereas *S. vulgare* var. *technicum* was less influenced - 27.7%. Maximum stimulatory effect of the combined application of Cycocel 750 SL on the initial development of *Sorghum* seedlings was observed in *S. sudanense* (48.4% at 3.0% w/v dose), followed by *S. bicolor* (34.3% at 2.6% w/v dose) and *S. vulgare* var. *technicum* (24.3% at 2.6% w/v dose) when compared to the control (p<0.05).

Therefore, we could recommend the priming of *Sorghum* seeds with Cycocel 750 SL as an effective practice to enhance the germination and to reduce the biologically delayed seed emergence which will increase their competitiveness against weed infestation. The combined treatment of *Sorghum* genotypes with this growth regulator (seed priming and foliar application) at 1.5-2.6% w/v concentrations could enhance the biomass synthesis and initial development of seedlings with more than 50% (dependent to the genotype response).

References

Angelova, V., Ivanova, R., Delibaltova, V.K., & Ivanov, I. (2011). Use of sorghum crops for *in situ* phytoremediation of polluted soils. *Journal of Agricultural Science and Technology*, A1, 693-702.

Afria, S., Nathawat, N., & Yadav, M. (1998). Effect of cycocel and saline irrigation of physiological attributes, yield and its components in different varieties of Guar (*Cyamopsis tetragonoloba* L. Taub). *Indian Journal of Plant Physiology, 3*, 46–48.

Afzal, I., Basara, S., Farooq, M., & Nawaz, A. (2006). Alleviation of salinity stress in spring wheat by hormonal priming with ABA, salicylic acid and ascorbic acid. *International Journal of Agriculture and Biology*, *8*, 23-28.

BASF Fact Sheet. 2019. Cycocel® 750. Plant growth regulant for wheat, oats and perennial ryegrass seed crops. Retrieved from crop-solutions.basf.co.nz.

Berenji, J., & Dahlberg, J. (2004). Perspectives of Sorghum in Europe. *Journal of Agronomy* *and Crop Science, 190*, 332-338. doi:10.1111/j.1439-037X.2004.00102.x.

Bibi, A., & Ali, S. (2012). Combining ability analysis for green forage associated traits in sorghum-sudangrass hybrids under water stress. *International Journal for Agro Veterinary and Medical Sciences*, *6*(2), 115-137.

Bahrami, K., Anosheh, H., & Emam, Y. (2014). Growth parameters changes of barley cultivars as affected by different cycocel concentration. *Crop Physiology*, *21*, 17-27.

Child, R.D. (1984). Effect of growth retardants and ethaphon on growth and yield formation of oilseed rape. *Aspects of Applied Biology Agronomy, Physiology, Plant Breeding and Crop Protection of Oilseed Rape, (6)*, 127-136.

Cifuentes, R., Bressani, R., & Rolz, C. (2014). The potential of sweet sorghum as a source of ethanol and protein. *Energy for Sustainable Development, 21*, 13–19. doi: 10.1016/j.esd.2014.04.002.

Daws, M., Ballard, C., Mullins, C., Garwood, N., Murray, B., Pearson, T., & Burslem, D. (2007). Allometric relationships between seed mass and seedling characteristics reveal trade-offs for neotropical gap-dependent species. *Oecologia, 154*, 445–454. doi:10.1007/s00442-007-0848-2.

Gianfagna, T. (1995). Natural and synthetic growth regulators and their use in horticultural and agronomic crops. In Davies P. (Ed.). *Plant hormones: physiology, biochemistry and molecular biology* (pp. 751-774). Dordrecht: Kluwer Academic Publishers.

Hinkelmann, K., & Kempthorne, O. (1994). *Design and analysis of experiments. Vol. I: Introduction to experimental design*. New York: John Wiley and Sons. Inc.

House, L. (1985). *A Guide to Sorghum Breeding. International Crops Research Institute for the Semiarid Tropics* (2nd Edition). Patancheru, India: ICRISAT. Retrieved from oar.icrisat.org.

Islam, A., Anuar, N., & Yaakob, Z. (2009). Effect of genotypes and pre-sowing treatments on seed germination behavior of Jatropha. *Asian Journal of Plant Sciences, 8*, 433-439. doi: 10.3923/ajps.2009.433.439.

Ismaeil, M., Khafagi, O., Kishk, E., & Sohsah, S. (1993). Effect of some seed hardening treatments on germination, growth and yield of Sudan grass grown under saline conditions. *Desert Institute Bulletin of Egypt*, *43*, 221– 242

ISTA. (1985). International Seed Testing Association. Rules for seed testing. *Seed Science and Technology, 13*, 300–520.

Fromme, D., Dotray, P., Grichar, W., & Fernandez, C. (2012). Weed Control and Grain Sorghum (*Sorghum bicolor*) Tolerance to Pyrasulfotole plus Bromoxynil. *International Journal of Agronomy*, Article ID 951454, 10 pages. doi:10.1155/2012/951454.

Jamshidi, S., Hashemizadeh, S., & Shahrokhi, S. (2011). Assessment of Auto-allelopatic Potential of Broomcorn (*Sorghum vulgare* var. *technicum*). *International Conference on Asia Agriculture and Animal IPCBEE, 13*, 116-120.

Lau, J., Puliafico, K., Kopshever, J., Steltzer, H., Jarvis, E., Schwarzländer, M., Strauss, S., & Hufbauer, R. (2008). Inference of allelopathy is complicated by effects of activated carbon on plant growth. *New Phytologist*, *178*, 412–423.

Lutts, S., Benincasa, P., Wojtyla, L., Kubala, S., Pace, R., Lechowska, K., Quinet, M., & Garnczarska, M. (2016). Seed priming: new comprehensive approaches for an old empirical technique, new challenges in seed biology. In: Araújo S., & Balestrazzi, A. (Eds.) *Basic and translational research driving seed technology*. Rijeka: InTech Open. doi: 10.5772/64420.

North, J., C., & Ndankidemi, P. (2010). Effect of the growth retardant Cycocel in controlling the growth of *Dombeya burgessiae*. *African Journal of Biotechnology*, *9*(29), 4529-4533. doi: 10.5897/AJB10.1666.

Marinov-Serafimov, P., & Golubinova, I. (2015). Sudan Grass Sensitivity to Some Herbicides. II. Productivity. *Plant Science*, *52*(6), 13-20. doi:10.1016/B978-0-12-394314-9.00003-8.

Mundia, C., Secchi, S., Akamani, K., & Wang, G. (2019). A Regional Comparison of Factors Affecting Global Sorghum Production. *The Case of North America, Asia and Africa's Sahel, Sustainability, MDPI, Open Access Journal*, *11*(7), 1-18.

Moyer, J., Fritz, J., & Higgins, J. (2003). Relationships among forage yield and quality factors of hay-type sorghum. *Online Crops Management* doi:10.1094/CM-2003-1209-01-RS.

Nasr, M., & Mansour, S. (2005). The use of allelochemicals to delay germination of *Astragalus cycluphyllus* seeds. *Journal of Agronomy*, *4*(2), 147-150. doi:10.3923/ja.2005.147.150.

Pirasteh-Anosheh, H., Emam, Y., & Ashraf, M. (2014). Impact of Cycocel on seed germination and growth in some commercial crops under osmotic stress conditions. *Archives of Agronomy and Soil Science*, *60*(9), 1277-1289. doi:10.1080/03650340.2013.879119.

Pirasteh-Anosheh, H., Emam, Y., & Khaliq, A. (2016). Response of cereals to cycocel application. *Iran Agricultural Research*, *35*(1), 1-12.

Pourmohammad, A., Shekari, F., & Soltaniband, V. (2013). Effects of cycocel priming on growth and early development of rapeseed under drought stress. *Acta Universitatis Sapientiae Agriculture and Environment*, *5*, 5-18. doi:10.2478/ausae-2014-0001.

Popescu, A., & Condei, R. (2014). Some considerations on the prospects of Sorghum crop. - *Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development*, *14*(3), 295-304.

Serna-Saldívar, S. O., Chuck-Hernández, C., Pérez-Carillo, E., & Heredia-Olea, E. (2012). Sorghum as a multifunction crop for the production of fuel ethanol: current status and future trends. In: Lima, M.A.P. (Ed.). *Bioethanol*. London, UK: InTech. Retreived from cdn.intechweb.org.

Singh, P., Pandey, A, & Khan, A. (2017). Effect of seed priming on growth, physiology and yield of lentil (*Lens culinaris* Medie) Cv. Ndl-1. *Journal of Pharmacognosy and Phytochemistry*, *SP1*, 717-719.

Silva, C., da Silva, A., do Vale, W., Galon, L., Petter, FA., & Karam, D. (2014). Weed interference in the sweet sorghum crop. *Bragantia Campinas*, *73*, 438-445. doi:10.1590/1678-4499.0119.

Shahrokhi, Sh., Hejazi, S.N., Khodabandeh, H., Farboodi, M., & Faramarzi, A. (2011). Allelopathic effect of aqueous extracts of pigweed *Amaranthus retroflexus* L. organs on germination and growth of five barley cultivars. *International Conference on Chemical, Biological and Environmental Engineering*, *20*, 80-84.

Statgraphics Plus. 1994. *Reference Manual Version 2.1 for Windows (DOS).* Cambridge: Statgraphics Plus Bitstream.

StatSoft Inc. (2010). *STATISTICA (data analysis software system), version 10.* Retrieved from statsoft.com.

Stefaniak, T., Dahlberg, J., Bean, B., Dighe, N., Wolfrum, E., & Rooney, W. (2012). Variation in biomass composition components among forage, biomass, sorghum-sudangrass, and sweet sorghum types. *Crop Science*, *52*, 1949–1954. doi:10.2135/cropsci2011.10.0534.

Surendra, M. P., & Pota, K.B. (1978). On the allelopathic potentials of root exudates from different ages of *Celosia argenta* L. *National Academy Science Letters*, *1*, 56-58.

Uzun, F., Ugur, S., & Sulak, M. (2009). Yield, Nutritional and Chemical Properties of Some Sorghum x Sudan Grass Hybrids (*Sorghum bicolour* (L.) Moench x *Sorghum sudanense* Stapf.). *Journal of Animal and Veterinary Advances*, *8*, 1602-1608.

Zheng, M., Tao, Y., Hussain, S., Jiang, Q., Peng, S., Huang, J., Cui, K., & Nie, L. (2016). Seed priming in dry direct-seeded rice: consequences for emergence, seedling growth and associated metabolic events under drought stress. *Plant Growth Regulation*, *78*, 167-178. doi:10.1007/s10725-015-0083-5.

Received: 26.11.2019
Accepted: 26.03.2020