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Allelopathic effect between seeds of *Sorghum vulgare* var. *technicum* [Körn.] and *Sinapis alba* L.

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Abstract

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The allelopathic effect of co-germination of *Sorghum vulgare* var. *technicum* Körn. seeds and *Sinapis alba* L. has been studied under laboratory conditions. Some correlations have been observed. A stimulating effect of 8.9 to 50.0% has been found during the germination of *Sorghum vulgare* var. *technicum* Körn. within the co-germination of seeds from different genotypes of technical broom (donor) and seeds of white mustard (acceptor). The co-germination of *Sinapis alba* L. seeds as a donor and seeds of various technical broth genotypes (*Sorghum vulgare* var. *technicum* Körn.) as an acceptor is proving both inhibiting and stimulating effect on seed germination of the technical broom. The inhibiting effect for local varieties is from 8.2 to 33.3%. A stimulating effect (IEA = -50.0%) is found in Szegedi 1023 variety. The highest overall allelopathic potential (OAP) has provisionally been determined in the broomcorn local varieties S14, MI16N and GL15A with the proximity of white mustard seedlings. The lowest OAP (from 0.1 to 0.3) is for the Szegedi 1023 variety, followed by the PL 16 variety with OAP from 0.5 to 0.6. Local varieties of technical broom PL 16, Mi16N and Szegedi 1023 variety have allelopathic potential, as they have not shown a statistically inhibitory effect on white mustard. These genotypes can be used as future selection program components.

Keywords: Sorghum vulgare var. *technicum*; *Sinapis alba*; germination; interference; seedling growth

Introduction

An undeniable and expensive consequence of agricultural practices is the adaptation and the high biological and environmental plasticity of the weeds, that facilitates their rapid dissemination to the agricultural fields. Weeds are responsible for the significant crop yield losses and for the financial losses of agricultural production – in the order of 10% per year worldwide (Oerke, 2006; Baucom and Holt, 2009; Hassannejad et al., 2013). In the last decades the research work was focused on the study of allelopathic interrelations between cultivated plants and weed species with the purpose to finding varieties with high allelopathic potential (Bertholdsson, 2010; Blum, 2014).

According to Ebana et al. (2001) and Olofsdotter (2001) allelopathy can be considered as a means in the breeding programmes for biological control against weeds. The discovery of varieties with high allelopathic potential provides a possibility for decrease of the inputs in agricultural crop growing and production of ecologically pure foods (Labrada, 2003; Jabran and Farooq, 2013). It was found that *Sorghum* species possess a number of water soluble allelochemicals which are phytotoxic to the growth of some weed species such as *Phalaris minor* Retz., *Chenopodium album* L., *Rumex dentatus* L. and *Convolvulus arvensis* L. (Cheema and Khaliq, 2000). According to Marchi et al. (2008), Jamshidi et al. (2011), Sabahie et al. (2014) residues of *Sorghum* species have been used for a biological management of weeds.

Cheema et al. (2001) used successfully Sorghaab (sorghum stem water extract) as a natural weed inhibitor for weed management in field with spring mung bean.

In the literature there is data on variety differences with regard to the allelopathic potential in different sorghum species (Cheema et al., 2008; Sabahie et al., 2014; Głąb et al., 2017) and limited for the *Sorghum vulgare* var. *technicum* (Jamshidi et al., 2011).

The objective of this study was to examine the allelopathic effect in co-germination of seeds of genotypes technical broom (*Sorghum vulgare* var. *technicum* Körn.) and seeds of white mustard (*Sinapis alba* L.) and discovery of genotype specimens of a technical broom with allelopathic potential for their inclusion as components in future selection programs.

Materials and Methods

Collection and preparation of plant material

The seeds of broomcorn varieties (*Sorghum vulgare* var. *technicum*) were taken from operational collections of the Institute of Forage Crops – Pleven, Bulgaria (Table 1).

Bioassay

In order to determine the effects of interaction seed to seed between broomcorn (*Sorghum vulgare* var. *technicum* Körn.) and white mustard (*Sinapis alba* L.) on seed and seedling growth factors, an experiment was carried out as complete randomized block design with four replications in laboratory condition by the method of Ghafarbi et al. (2012).

Seeds of broomcorn or white mustard as control were counted and 16 seeds of each species as separate were placed within Petri dishes (diameter 90 mm) between filter paper moistened with 5 ml of distilled water. For survey the effect of neighboring different genotypes broomcorn seeds on seed and seedling factors of white mustard, numbers of 16 seeds of each broomcorn genotypes were regularly placed between the 16 white mustard seeds. The distance between adjacent seeds was 0.5 cm, forming a grid of 4 rows by 4 columns of white mustard and seeds of each genotype broomcorn (Ghafarbi et al., 2012). The samples were then placed in a thermostat-operated device at a temperature of 22 ± 2°C for seven days.

Effect assessment

For assessing experimental results, the following parameters were used:

1. Quantitative parameters: the number of germinated seeds in each treatment; percent of germination in each variant (%);

2. Biometric parameters: root, stem and seedling length (cm); fresh biomass weight per seedling (g) for each broomcorn genotypes and white mustard. Length was measured using graph paper and weight on an analytical balance;

3. Statistical evaluation and calculated formulas:

Germination seeds ($GS_{\%}$) was determined by the equation (1) prescribed according to ISTA (1985).

$$GS = \frac{Numbers\ of\ seed\ germinated}{Total\ number\ of\ seed\ plated} \quad (1)$$

Inhibition effect (IE) was determined by the equation (2) (Ahn and Chung, 2000):

$$IE = \frac{[C - T]}{C}.100, \quad (2)$$

where C – measurement of the control variant for the different genotypes broomcorn or white mustard; *T* – measurement of each interaction treatment „broomcorn ÷ white mustard“.

Overall allelopathic potential (OAP) was determined an adapted formula by Smith (2013), equation (3):

$$OAP = \text{mean}\ (IB + IW)/100 \quad (3)$$

where *IB* – percent inhibition of germination seeds, seedling growth and fresh biomass of the seedling compared to each control variants of broomcorn genotypes and *IW* – percent inhibition of germination seeds, seedling growth and fresh

Table 1. Broomcorn (*Sorghum vulgare* var. *technicum*) genotypes investigated and white mustard (*Sinapis alba* L.)

№	Species	Genotypes	Type of plants
1.	Szegedi 1023	Variety	dwarf
2.	S14	Local varieties from Southeast Bulgaria	dwarf
3.	G16V	Local varieties from Central Northern Bulgaria	medium-high
4.	PL16	Local varieties from Central Northern Bulgaria	above average
5.	GL15A	Local varieties from Central Northern Bulgaria	medium-high
6.	Mi 16N	Local varieties from Central Northern Bulgaria	high
7.	*Sinapis alba* L.		

biomass of the seedling compared to the control treatment at white mustard. Using the mean of the sum of the radical percentage inhibitions divided by 10, a score between 1.0 and 10.0 was obtained and the data were ranked according to this score. A maximum score of 10.0 would indicate that the test interaction between broomcorn genotypes and white mustard had totally inhibited growth, while a score of 0.0 would indicate that no allelopathic inhibition had occurred.

The percentage of seed germination in each treatment was previously transformed by the equation (4) (Hinkelmann and Kempthorne, 1995):

$$Y = \arcsin\sqrt{\left(\frac{X\%}{100}\right)}, \quad (4)$$

where $x_{\%}$ – germinated seeds for each treatment (%).

The results obtained was calculated by programe product STATGRAPHICS Plus for Windows Version 2.1 at LSD P = 0.05.

Results and Discussion

Seed germination of the broomcorn (*Sorghum vulgare* var. *technicum*) in the control variants ranges from 90.0 to 75.5% and depends on the genotype (Table 2).

The highest percentage germinated seeds was recorded in Szegedi 1023 variety and in the local varieties G16V and PL16 and it is relatively lower in local varieties C14, GL15A and M16N. It is worth noting that the differences between them was significant at P = 0.05.

Germination percentage of neighboring seeds of broomcorn and white mustard (*Sinapis alba* L.) in co-development with variety Szegedi 1023 and local varieties G16V and PL16 was not significant (P = 0.05). However, proximity seeds of white mustard had inhibitory effect (from 8.2 to 33.3%) on germination rate of broomcorn seeds from G16V, PL16 and Mi 16N local varieties, and the differences were statistically significant (P = 0.05).

The proximity of broomcorn genotype seeds of Szegedi 1023 variety and Mi16N variety had inhibitory effect (respectively 33.3 and 16.1%) on germination rate of white mustard seeds. However, seeds of broomcorn local varieties S14, PL16, GL15A had a negligible inhibitory effect on the germination of white mustard seeds compared to the control variants (Table 2).

Consequently, the co-development of neighboring seeds of local variety Mi 16N with seeds of white mustard exhibited mutual inhibition (IE_A 23.0% and IE_B 16.1%) for both species. The differences are statistically proven compared to control variants for each species at P = 0.05 (Table 2).

The interaction of broomcorn genotype seeds (donor) and white mustard seeds (acceptor) of the seed germination had stimulated effect, and could be ranged in the following ascending order: Mi16N (-8.9%) > S14 and GL16A (-19.2%) > G16V (-29.9%) > PL 16 (-50.0%). Exceptions were found for the interaction of broomcorn seeds of Szegedi 1023 variety and white mustard seeds where it established had inhibitory effect (33.3%).

Reciprocal interaction of neighboring mustard seeds (donor) and broomcorn genotypes seeds (acceptor) shows an

Table 2
Comparison of germination percentage of broomcorn (*Sorghum vulgare* var. *technicum*) genotypes seeds in response to neighbouring white mustard (*Sinapis alba* L.) seeds

№	Donor			Acceptor			Interaction		OAP
	Genotypes of *Sorghum vulgare* var. *technicum*	$GS_{\%A}$	IE_A	Weed	$GS_{\%B}$	IE_B	IE_D	IE_A	
1	Szegedi 1023 Control [A]	90.0d		*S. alba* Control[B]	90,0c				
	Szegedi 1023	90.0d	0.0	*S. alba*	60.0a	33.3	33.3	–50.0	0.3
2	S14 Control [A]	75.5c		–	–	–	–	–	–
	S14	75.5c	0.0	*S. alba*	90.0c	0.0	–19.2	16.1	0.0
3	Mi 16N Control [A]	90.0d		–	–	–	–	–	–
	Mi 16N	69.3b	23.0	*S. alba*	75.5b	16.1	–8.9	8.2	0.4
4	PL16 Control [A]	90.0d		–	–	–	–	–	–
	PL16	60.0a	33.3	*S. alba*	90.0c	0.0	–50.0	33.3	0.3
5	GL15A Control [A]	75.5c		–	–	–	–	–	–
	GL15A	75.5c	0.0	*S. alba*	90.0c	0.0	–19.2	16.1	0.0
6	G16V Control [A]	75.5c		–	–	–	–	–	–
	G16V	69.3b	8.2	*S. alba*	90.0c	0.0	–29.9	23.0	0.08

a, b, c, d LSD at P = 0.05 confidence interval; $GS_{\%}$ – germination seeds; IE – inhibition effect; OAP – overall allelopathic potential inhibitory effect on seed germination IE_A of 8.2 to 33.3% for local varieties, whereas in variety Szgedi 1023 it has a stimulating effect (IE_A = -50.0%).

The overall allelopathic potential (OAP) of the neighboring seeds of broomcorn genotypes and white mustard is in the range of 0.0 to 0.4. The highest overall allelopathic potential (OAP) was determined conditionally at broomcorn local variety Mi16N on both the test species "broomcorn-white mustard", with a value of more than 0.4 OAP and lowest for a local variety G16V – 0.08 OAP. Similar results were reported by Aliloo et al. (2012) and Hassannejad et al. (2013). According to them seed germination is a critical phase in the life-cycle of every plant. During this phase the forces (biotic and abiotic stresses) have a maximum opportunity to exert their influence.

The data of biometric measurements of length of root (cm) enabled an objective estimation of differences in the initial development stages of tested broomcorn genotypes, depending on the proximity development with white mustard (Table 3).

A specific varietal response was found in the broomcorn genotypes relative to root length increase as compared to the control variants. In genotypes Szegedi 1023, PL 16, the GL15A and Mi16N inhibition rates were 45.9, 31.1, 12.3 and 1.8%, respectively, and the differences were statistically significantly reduced at P = 0.05 only for variety Szegedi 1023 and the local variety PL 16. In the local varieties S14 and G16V an statistically unsignificantly stimulating effect of 11.0 to 14.4% according the control variants was found.

Mean length of the shoot in genotypes broomcorn variety Szegedi 1023 and local variety PL16 is reduced respectively 39.8 and 51.3% of the neighborhood of white mustard, compared to control variants. It was found that the genotypes GL15A and G16V have a negligible stimulatory (from -2.9 to -8.8%) and low inhibitory effect (to 17.1%) at the length of the shoot and the differences being statistically insignificant compared to the control variants.

The average length of shoots in local variety Mi16N is found to have a statistically significant stimulating effect -28.9 to adjacency by white mustard seedling, relative to the control variant. The strongest inhibitory effect on seedlings length and growth was established at the Szegedi 1023 variety and at the local variety PL 16 was significantly different to other local varieties and IE_A is 42.0 and 43.3% and can be identified as susceptible to proximity of white mustard seeds.

It was established that the average length of the white mustard root in co-development with local varieties of local varieties S14, Mi16N, GL15A and G16V of broomcorn was inhibited from 27.1 to 41.4% as compared to the control variants. The differences were statistically significant at P = 0.05. In contrast, root length of white mustard in the presence of seeds of variety Szegedi 1023 and local variety PL16 had relative low significantly inhibited effect, as root length of white mustard is respectively 12.9% and 16.7% lower compared to the control variants.

Table 3

Comparison of root, shoot and seedling length of interaction broomcorn (*Sorghum vulgare* var. *technicum*) genotypes investigated and white mustard (*Sinapis alba* L.)

№	Donor					Acceptor					Interaction		OAP
	Genotypes *Sorghum vulgare* var. *technicum*	Root, cm	Shoot, cm	Seedling, cm	IE_A	Weed	Root, cm	Shoot, cm	Seedling, cm	IE_B	IE_D	IE_A	
1	Szegedi 1023 Control [A]	4.16d	3.09bc	7.25b		*S. alba* Control	2.10c	2.00b	4.08b				
	Szegedi 1023	2.25ab	1.86a	4.11a	43.3	*S alba*	1.83bc	1.97b	3.80b	6.9	7.5	–8.2	0.5
2	S14 Control [A]	3.00bc	3.50bcd	6.50b		–	–	–	–	–	–	–	–
	S14	3.33c	2.90b	6.23b	4.2	*S alba*	1.53b	1.90b	3.43ab	15.9	44.9	–81.6	0.2
3	Mi 16N Control [A]	5.53e	2.94b	8.47c		–	–	–	–	–	–	–	–
	Mi 16N	5.43e	3.79de	9.21cde	–8.7	*S.alba*	1.50ab	1.54a	3.04a	25.5	67.0	–203.0	0.2
4	PL16 Control [A]	3.09c	3.59cde	6.69b		–	–	–	–	–	–	–	–
	PL16	2.13a	1.75a	3.88a	42.0	*S. alba*	1.75bc	1.78ab	3.50ab	14.2	9.8	–10.9	0.6
5	GL15A Control [A]	6.50f	3.83de	10.21e		–	–	–	–	–	–	–	–
	GL15A	5.70ef	4.17e	9.75de	4.5	*S. alba*	1.23a	1.91b	3.13a	23.3	67.9	–211.5	0.3
6	G16V Control [A]	5.40e	3.40bcd	8.63cd		–	–	–	–	–	–	–	–
	G16V	6.18ef	3.50bcd	9.63cde	–11.6	*S. alba*	1.27a	1.78ab	3.08a	24.5	68.0	–212.7	0.1

a, b, c, d LSD at P=0.05 confidence interval; IE – inhibition effect; OAP – overall allelopathic potential

Shoot lenght of white mustard were insignificantly reduced (from 1.5 to 11.0%) by beside of the proximity of local variety Mi16N – 23.0%, than to control variant, where differences are statistically significant at P = 0.05.

The proximity of white mustard seeds and tested broomcorn local varieties Mi 16N, GL15A and G16V seeds had inhibitory effect from IE_B 23.3 to 25.5% on the growth of seedlings of white mustard, while the neighboring of seeds of broomcorn genotypes variety Szegedi 1023 and local varieties S14, PL16 had statistically insignificant inhibitory effects (IE_B from 6.9 to 15.9%) on the growth of seedlings of white mustard, than control variants (Table 3).

The IE_D values varied from 7.5 to 68.0% at the interaction „broomcorn genotype seedlings (donor) – and white mustard seedlings (acceptor)“ and for the reciprocal interaction IE_A values varied from -8.2 to 212.7% and could be conventionally grouped in the following ascending order: Szegedi 1023 > PL 16 > S14 > Mi16N > GL16A > G16V.

The differences in the IE_D and IE_A at the growth of the seedlings in the interaction in broomcorn – *Sinapis alba* can be explained by genetic differences, because the comparisons between plant species were made under equal conditions.

The values of OAP by interaction of the growth of the seedlings on the tested broomcorn genotipes and white mustard ranged from 0.1 to 0.6. The highest OAP was determined conditionally at broomcorn local varieties S14, MI16N and GL15A with the proximity of growth of the seedlings of white mustard, and the lowest OAP (from the fresh mass of germinated seeds of technical broom genotypes) is statistically significantly reduced (P = 0.05) and IE_A is from 33.3 to 50.0% at the S14, Mi16N, PL16 and GL15 according to each control variants. In contrast, broomcorn Szegedi 1023 and G16V in the presence of white mustard had no inhibitory effect compared to control variants IE_B is 25.0% (Table 4).

Conclusions

The studied varieties showed different susceptibility to the allelopathic effect from together seed germination and initial development from *Sorghum vulgare* var. *technicum* Körn. and *Sinapis alba* L. as a result, release of allelopatic substances from seeds of both plant species would be the responsible for the observed effects.

Interaction between the neighboring seeds between different broomcorn seeds genotypes (*Sorghum vulgare* var. *technicum*) (donor) to seed white mustard (*Sinapis alba* L.) (acceptor) showed an stimulated effect from 8.9 to 50.0% on the seed germination of *Sorghum vulgare* var. *technicum*.

Reciprocal interaction of neighboring mustard seeds *Sinapis alba* L.) (donor) and broomcorn genotipes (*Sorghum vulgare* var. *technicum*) (acceptor) shows an inhibitory effect on seed germination IE_A of 8.2 to 33.3% for local varieties, whereas in variety Szgedi 1023 it shows a stimulating effect (IE_A = -50.0%).

The highest overall allelopathic potential was determined conditionally at broomcorn local varieties S14, MI16N and

Table 4
Comparison of sedleeng fresh weight of interaction broomcorn (*Sorghum vulgare* var. *technicum*) genotypes investigated and white mustard (*Sinapis alba* L.)

№	Donor			Acceptor			Interaction		OAP
	Genotypes *Sorghum vulgare* var. *technicum*	Seedling, g	IE_A	Weed species	Seedling, g	IE_B	IE_D	IE_A	
1	Szegedi 1023 Control ^{A}	0.06c		*S. alba* Control	0.04b				
	Szegedi 1023	0.06c	0.0	*S. alba*	0.04b	0.0	33.3	–50.0	0.00
2	S14 Control ^{A}	0.1e		–	–	–	–	–	–
	S14	0.06c	40.0	*S. alba*	0.03a	25.0	50.0	–100.0	0.7
3	Mi 16N Control ^{A}	0.08d		–	–	–	–	–	–
	Mi 16N	0.06c	25.0	*S. alba*	0.03a	25.0	50.0	–100.0	0.5
4	PL16 Control ^{A}	0.04b		–	–	–	–	–	–
	PL16	0.02a	50.0	*S. alba*	0.04b	0.0	–100.0	–50.0	0.5
5	GL15A Control ^{A}	0.12f		–	–	–	–	–	–
	GL15A	0.08d	33.3	*S. alba*	0.03a	25.0	62.5	–166.7	0.6
6	G16V Control ^{A}	0.08d		–	–	–	–	–	–
	G16V	0.08d	0.0	*S. alba*	0.04b	0.0	0.0	100.0	0.0

a, b, c, d LSD at P = 0.05 confidence interval; IE – inhibition effect; OAP – overall allelopathic potential

GL15A and it is from 0.1 to 0.3 for a variety Szegedi 1023 and for local variety PL 16 is from 0.5 to 0.6.

Local varieties PL 16, Mi16N and variety Szegedi 1023 have allopathic tolerance, because no statistically significant inhibitory effect of the studied interaction was found in them. These genotypes can be used as components in future breeding programs.

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