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

Plamen Marinov-Serafimov¹, Irena Golubinova¹, Shteliana Kalinova²

¹Institute of Forage Crops, 89, Gen. Vladimir Vazov Str., 5800 Pleven, Bulgaria  
²Agricultural University, 12, Mendeleev Str., 4000 Plovdiv, Bulgaria  
*Corresponding author: plserafimov@abv.bg*

Abstract


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).

\[
GS = \frac{\text{Numbers of seed germinated}}{\text{Total number of seed plated}} 
\]

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

\[
IE = \frac{[C - T]}{C} \times 100, 
\]

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):

\[
OAP = \text{mean } (IB + IW)/100 
\]

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 biomass.

**Table 1. Broomcorn**

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

<table>
<thead>
<tr>
<th>№</th>
<th>Species</th>
<th>Genotypes</th>
<th>Type of plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Szegedi 1023</td>
<td>Variety</td>
<td>dwarf</td>
</tr>
<tr>
<td>2.</td>
<td>S14</td>
<td>Local varieties from Southeast Bulgaria</td>
<td>dwarf</td>
</tr>
<tr>
<td>3.</td>
<td>G16V</td>
<td>Local varieties from Central Northern Bulgaria</td>
<td>medium-high</td>
</tr>
<tr>
<td>4.</td>
<td>PL16</td>
<td>Local varieties from Central Northern Bulgaria</td>
<td>above average</td>
</tr>
<tr>
<td>5.</td>
<td>GL15A</td>
<td>Local varieties from Central Northern Bulgaria</td>
<td>medium-high</td>
</tr>
<tr>
<td>6.</td>
<td>Mi 16N</td>
<td>Local varieties from Central Northern Bulgaria</td>
<td>high</td>
</tr>
<tr>
<td>7.</td>
<td><em>Sinapis alba</em> L.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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):

\[ Y = \arcsin \left( \frac{\%}{100} \right) \]

where \( \% \) – 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 (\textit{Sorghum vulgare} var. \textit{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 (\textit{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 (\textit{Sorghum vulgare} var. \textit{technicum}) genotypes seeds in response to neighbouring white mustard (\textit{Sinapis alba} L.) seeds

<table>
<thead>
<tr>
<th>№</th>
<th>Donor</th>
<th>Acceptor</th>
<th>Interaction</th>
<th>OAP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Genotypes of \textit{Sorghum vulgare} var. \textit{technicum}</td>
<td>GS_A</td>
<td>IE_A</td>
<td>Weed</td>
</tr>
<tr>
<td>1</td>
<td>G1023 Control</td>
<td>90.0d</td>
<td>S. alba Control</td>
<td>90.0c</td>
</tr>
<tr>
<td></td>
<td>Szegedi 1023</td>
<td>90.0d</td>
<td>0.0</td>
<td>S. alba</td>
</tr>
<tr>
<td>2</td>
<td>S14 Control</td>
<td>75.5c</td>
<td>0.0</td>
<td>S. alba</td>
</tr>
<tr>
<td>3</td>
<td>Mi 16N Control</td>
<td>90.0d</td>
<td>0.0</td>
<td>S. alba</td>
</tr>
<tr>
<td>4</td>
<td>PL16 Control</td>
<td>90.0d</td>
<td>0.0</td>
<td>S. alba</td>
</tr>
<tr>
<td>5</td>
<td>GL15A Control</td>
<td>69.3b</td>
<td>23.0</td>
<td>S. alba</td>
</tr>
<tr>
<td>6</td>
<td>G16V Control</td>
<td>60.0a</td>
<td>33.3</td>
<td>S. alba</td>
</tr>
</tbody>
</table>

a, b, c, d LSD at \( P = 0.05 \) confidence interval; GS\_A – 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 Szegedi 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, PL16, 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 insignificantly 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.)

<table>
<thead>
<tr>
<th>№</th>
<th>Genotypes Sorghum vulgare var. technicum</th>
<th>Donor Root, cm</th>
<th>Shoot, cm</th>
<th>Seedling, cm</th>
<th>IE$_A$</th>
<th>Acceptor Weed Root, cm</th>
<th>Shoot, cm</th>
<th>Seedling, cm</th>
<th>IE$_B$</th>
<th>IE$_D$</th>
<th>IE$_A$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S. alba Control</td>
<td>4.16d</td>
<td>3.09bc</td>
<td>7.25b</td>
<td>43.3</td>
<td>S. alba</td>
<td>2.10c</td>
<td>2.00b</td>
<td>4.08b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>S. alba</td>
<td>2.25ab</td>
<td>1.86a</td>
<td>4.11a</td>
<td></td>
<td>S. alba</td>
<td>1.83bc</td>
<td>1.97b</td>
<td>3.80b</td>
<td>6.9</td>
<td>-8.2</td>
</tr>
<tr>
<td>3</td>
<td>S. alba</td>
<td>3.00bc</td>
<td>3.50bcd</td>
<td>6.50b</td>
<td></td>
<td>S. alba</td>
<td>1.53b</td>
<td>1.90b</td>
<td>3.43ab</td>
<td>15.9</td>
<td>44.9</td>
</tr>
<tr>
<td>4</td>
<td>S. alba</td>
<td>5.33c</td>
<td>2.90b</td>
<td>6.23b</td>
<td>4.2</td>
<td>S. alba</td>
<td>1.50ab</td>
<td>1.54a</td>
<td>3.04a</td>
<td>25.5</td>
<td>67.0</td>
</tr>
<tr>
<td>5</td>
<td>S. alba</td>
<td>5.43e</td>
<td>3.79de</td>
<td>9.21de</td>
<td>-8.7</td>
<td>S. alba</td>
<td>1.23a</td>
<td>1.78ab</td>
<td>3.50ab</td>
<td>14.2</td>
<td>9.8</td>
</tr>
<tr>
<td>6</td>
<td>S. alba</td>
<td>3.39c</td>
<td>3.59de</td>
<td>6.69b</td>
<td></td>
<td>S. alba</td>
<td>1.75bc</td>
<td>1.78ab</td>
<td>3.50ab</td>
<td>14.2</td>
<td>9.8</td>
</tr>
<tr>
<td>7</td>
<td>S. alba</td>
<td>6.50f</td>
<td>3.83de</td>
<td>10.21e</td>
<td></td>
<td>S. alba</td>
<td>1.75bc</td>
<td>1.78ab</td>
<td>3.50ab</td>
<td>14.2</td>
<td>9.8</td>
</tr>
<tr>
<td>8</td>
<td>S. alba</td>
<td>5.70ef</td>
<td>4.17e</td>
<td>9.75de</td>
<td>4.5</td>
<td>S. alba</td>
<td>1.23a</td>
<td>1.91b</td>
<td>3.13a</td>
<td>23.3</td>
<td>67.9</td>
</tr>
<tr>
<td>9</td>
<td>S. alba</td>
<td>5.40e</td>
<td>3.40bcd</td>
<td>8.63cd</td>
<td></td>
<td>S. alba</td>
<td>1.27a</td>
<td>1.78ab</td>
<td>3.08a</td>
<td>24.5</td>
<td>68.0</td>
</tr>
<tr>
<td>10</td>
<td>S. alba</td>
<td>6.18ef</td>
<td>3.50bcd</td>
<td>9.63de</td>
<td>-11.6</td>
<td>S. alba</td>
<td>1.27a</td>
<td>1.78ab</td>
<td>3.08a</td>
<td>24.5</td>
<td>68.0</td>
</tr>
</tbody>
</table>

a, b, c, d LSD at P=0.05 confidence interval; IE – inhibition effect; OAP – overall allelopathic potential
Shoot length 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 Mi16N, GL15A and G16V seeds had inhibitory effect from IEB 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 (IEB from 6.9 to 15.9%) on the growth of seedlings of white mustard, than control variants (Table 3).

The IED 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 IEA 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 IED and IEA 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 genotypes 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 IEA 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 IEA 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 allelopathic 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 a 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 IEA of 8.2 to 33.3% for local varieties, whereas in variety Szegedi 1023 it shows a stimulating effect (IEA = -50.0%).

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

Table 4

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

<table>
<thead>
<tr>
<th>№</th>
<th>Donor</th>
<th>Acceptor</th>
<th>Interaction</th>
<th>OAP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Genotypes Sorghum vulgare var. technicum</td>
<td>Seedling, g</td>
<td>IEA</td>
<td>Weed species</td>
</tr>
<tr>
<td>1</td>
<td>Szegedi 1023 Control A</td>
<td>0.06c</td>
<td>S. alba Control</td>
<td>0.04b</td>
</tr>
<tr>
<td>2</td>
<td>S14 Control A</td>
<td>0.06c</td>
<td>0.0</td>
<td>S. alba</td>
</tr>
<tr>
<td>3</td>
<td>S14</td>
<td>0.1e</td>
<td>40.0</td>
<td>S. alba</td>
</tr>
<tr>
<td>4</td>
<td>Mi 16N Control A</td>
<td>0.06c</td>
<td>25.0</td>
<td>S. alba</td>
</tr>
<tr>
<td>5</td>
<td>PL16 Control A</td>
<td>0.04b</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>GL15A Control A</td>
<td>0.02a</td>
<td>50.0</td>
<td>S. alba</td>
</tr>
<tr>
<td>6</td>
<td>GL15A</td>
<td>0.12f</td>
<td>33.3</td>
<td>S. alba</td>
</tr>
<tr>
<td>6</td>
<td>G16V Control A</td>
<td>0.08d</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>G16V</td>
<td>0.08d</td>
<td>0.0</td>
<td>S. alba</td>
</tr>
</tbody>
</table>

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 allelopathic 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.

References


Blum, U. (2014). Background for designing laboratory bioassays. *In Plant-Plant Allelopathic Interactions II* (pp. 1-29), Springer, Cham.


