ALLELOPATIC EFFECT OF FIVE WEED SPECIES ON SEED GERMINATION OF SORGHUM CROPS

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Abstract

Aim of this study was to evaluate the allelopathic effect of five invasive weeds (*Sorghum halepense* L. Pers., *Sonchus arvensis* L., *Cirsium arvense* L. Scop., *Xanthium strumarium* L.and *Aristolochia clematitis* L.) in forage crops on two *Sorghum* crops (*Sorghum sudanense* (Piper) Stapf and *Sorghum vulgare* var. *technicum* (Körn.)). An ex-situ experiment was carried out as follows: 10 seeds of each test variety were placed in Petri dishes between filter paper and the dried weed biomass extract was added at concentrations of 0.1, 0.2, 0.4, 0.8, 1.6 and 3.2% w/v. Petri dishes were placed in a thermostat-operated device at a temperature of 22 ± 2°C for a seven-days period. Distilled water was used as a control. Number of germinated seeds, % of seed germination against the control, and weed inhibition rate (IR) were measured. Our study revealed that the alellopathic effect of the tested five invasive weeds on seed germination of *S. sudanense* and *S. vulgare* var. *technicum* varied according to the plant species (both weed and cultural) and the concentration applied. Most pronounced negative effect on the germination process of *S. sudanense* seeds have expressed the cold aqueous extracts from *Sonchus arvensis* L. and *Cirsium arvense* (L.) Scop. – IR varied from 4.67-5.0% up to 70.3% at the highest test concentrations ($p<0.05$). Maximal inhibition of seed germination of *S. vulgare* var. *technicum* in comparison with the control was found at 3.2% w/v extract of *Sorghum halepense* (L.) Pers. (IR=58.4%), followed by the two highest concentrations of *Xanthium strumarium* L. extract (IR=41.6-45.9%).

Keywords: *interaction, allelopathy, seed germination, inhibition rate*

Introduction

Sorghum, originated in East Africa, is one of the first crops, which was taken into cultivation (House, 1985). At present, *Sorghum sudanense* hybrids are preferred as a fodder due to higher yields and tillering ratios and also their thin stems and higher leaf ratios (Uzun *et al.*, 2009). *Sorghum vulgare* var. *technicum* is mainly utilized for producing brooms, washing brushes, knittings, paper, wallboard, fences, biodegradable materials for packaging due to their peculiar resistance (Popescu and Condei, 2014). Sorghum cultivar plants are more tolerance to drought and high temperatures, diseases, pests, various soil types and show higher water use efficiency and, higher production capacity per unit area (Undersander and Lane, 2003; Uzun and Cigdem, 2005). Main disadvantage of Sorghum crops is their high sensitivity against weed infestation in the first 30-40 days after sowing (Marinov-Serafimov and Golubinova, 2015). Drastic effects of weeds on germination and growth on *Sorghum* and other crops are due to their competiveness with cultivated crops for resources and allelopathic potentials. Through allelopathy, weeds may cause significant effects on the growth and germination capacity of other crops. Weeds may possess diverse allelochemicals, which can interfere with other plants in a number of ways by either retarding or enhancing the germination and growth of receiving plants (Oerke, 2006; Marinov-Serafimov and Golubinova, 2015).

The summarized results of the experimental work of Cheema *et al*. (2002; 2008), Alsaadawi and Dayan (2009), Jesudas e*t al*. (2014), Głąb *et al*. (2017), Jabran (2017) show that the skrining to determine the allelopathic effect of species of the genus Sorghum on germination and initial development of a number of weed species has been well performed. Allelopathic interference in the system "weed - Sorghum crop" has been poorly studied (Shahrokhi *et al*., 2011; Asghar *et al*., 2013; Dafaallah and El-Twom, 2017), necessitating the establishment of allelopathic tolerance of Sorghum crops towards invasive weed species.
Aim of this study was to evaluate the allelopathic effect of five invasive annual and perennial dicotyledonous weed on germination and initial development at *Sorghum sudanense* (Piper) Stapf and *Sorghum vulgare* var. *technicum* (Körn.) in order to determine species sensitivity which could serve as a means of increasing efficiency in the early stages of the selection process.

Material and Methods

Collection of weed material and preparation of cold aqueous extracts

Aboveground biomass from five invasive weed species (*Sorghum halepense* (L.) Pers., *Sonchus arvensis* L., *Cirsium arvense* (L.) Scop., *Xanthium strumarium* L., *Aristolochia clematitis* L.) in forage crops was collected in a natural environment of weed infestation in the Institute of Forage Crops, Pleven at BBCH 51-55 (Hess *et al*., 1997). No separated aboveground biomass of available weed species was chopped together to the length of 0.5-3.0 cm, drying to a constant dry weight at 50 ± 5°C and was grind in a grinder Retsch SM – 1 at a sieve size of 1.0 mm. Cold aqueous extracts of dry weed aboveground biomass were prepared as follows: 100 g of dry weed biomass were soaked in 1 l distilled water and leaved at a temperature of 24 ± 20C for 24 h in a shuttle apparatus at 240/60 c^{-1}. After that they were decanted, filtered through filter paper and centrifuged in K24 centrifuge at 5000/60 s^{-1}. From these stock solutions were prepared test extracts of each weed plant with concentrations of 0.1%, 0.2%, 0.4%, 0.8%, 1.6% and 3.2% w/v, respectively. The experimental data were evaluated 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 and Statistica Ver. 10.

Experimental design

Ex-situ experiment was carried out as follows: 10 seeds of *S. sudanense* (300/43 mutant form) or *S. vulgare* var. *technicum* (local population), respectively, were placed into Petri dishes between paper and 10 ml weed test extract and one of the above mentioned concentrations were added. Seeds of the tested *Sorghum* genotypes were provided from the Selection Collection of the Institute of Forage Crops in Pleven, Bulgaria. Distilled water was used as a control. Each treatment consisted of three replicates including the control treatment. Samples were placed in a thermostat-operated device at 22 ± 2°C for 7 days and the number of germinated seeds, % of seed germination against the control, and weed inhibition rate, were measured. Percentage of seed germination was calculated after preliminary arcsin-transformation following the formula $Y=\arcsin\sqrt{(x\%/100)}$, forwarded by Hinkelman and Kempthorne (1994), and to induce half-maximal inhibition of growth (LC50) and P=0.05 confidence intervals were calculated according to Hamilton *et al.* (1977). Inhibition rate (IR) of tested weeds was calculated by the formula of Ahn and Chung (2000): $IR= 100 \times (n_{control} – n_{experiment})/n_{control}$, where n is the number of the germinated seeds. All collected data were analyzed using the software Statgraphics Plus for Windows Ver. 2.1 and Statistica Ver. 10.

Results and Discussion

Seed germination and seedling development are increasingly used in various bioassays as they allow the biological activity of various substances (herbicides, metabolites, allelochemicals

and even radionuclides) to be established with high reliability and low cost (Piotrowicz-Cieślak *et al*., 2010). Our study revealed that the alellopathic effect of the tested five invasive weeds on seed germination of *S. sudanense* and *S. vulgare* var. *technicum* varied according to the plant species (both weed and cultural) and the concentration applied (Table 1).
When regarding the experiments with seeds of *S. sudanense*, it was obvious that the most pronounced negative effect on the germination process expressed the cold aqueous extracts from *Sonchus arvensis* L. and *Cirsium arvense* (L.) Scop. – IR varied from 4.67-5.0% up to 70.3% at the highest test concentrations (p<0.05). Lowest inhibition was found under the extract from *Xanthium strumarium* L., where the % germination against the control was in the range between 63.0% - 92.56% and the IR had values from 7.4% to 37.0%. The extracts of the other two weed species - *Sorghum halepense* (L.) Pers. and *Aristolochia clematitis* L., also have medium expressed negative effect on the seed germination of *S. sudanense*, with the maximal values of IR=44.4% at 1.6% w/v concentration (Table 1).

Table 1. Allelopathic effect of five studied weed species on the seed germination of *S. sudanense* and *S. vulgare* var. *technicum*

Weed species	Concentration (w/v)	*Sorghum sudanense* (Piper) Stapf		*Sorghum vulgare* var. *technicum* Körn.	
		% germination against the control	Inhibition rate (IR)	% germination against the control	Inhibition rate (IR)
Sorghum halepense (L.) Pers.	0.1%	85.22cd	14.8	66.63c	33.4
	0.2%	81.44c	18.6	95.88e	4.1
	0.4%	81.44c	18.6	87.50d	12.5
	0.8%	92.56d	7.4	62.50bc	37.5
	1.6%	55.56a	44.4	58.38b	41.6
	3.2%	70.33b	29.7	41.63a	58.4
Sonchus arvensis L.	0.1%	85.22e	14.8	70.88bc	29.1
	0.2%	85.22e	14.8	62.50a	37.5
	0.4%	74.11d	25.9	62.50a	37.5
	0.8%	48.11c	51.9	87.50d	12.5
	1.6%	33.33b	66.7	66.63b	33.4
	3.2%	29.67a	70.3	62.50a	37.5
Cirsium arvense (L.) Scop.	0.1%	85.22e	14.8	83.38d	16.6
	0.2%	85.22e	14.8	87.50d	12.5
	0.4%	74.11d	25.9	58.38a	41.6
	0.8%	48.11c	51.9	66.63b	33.4
	1.6%	33.33ab	66.7	66.63b	33.4
	3.2%	29.67a	70.3	70.88c	29.1
Aristolochia clematitis L.	0.1%	85.22cd	14.8	79.13b	20.9
	0.2%	81.44c	18.6	100.00d	0.0
	0.4%	81.44c	18.6	79.13b	20.9
	0.8%	92.56d	7.4	75.00b	25.0
	1.6%	70.33b	29.7	91.63c	8.4
	3.2%	55.56a	44.4	58.38a	41.6
Xanthium	0.1%	85.22d	14.8	66.63c	33.4

strumarium L.	0.2%	92.56e	7.4	79.13d	20.9
	0.4%	74.11b	25.9	83.38e	16.6
	0.8%	77.78c	22.2	87.50f	12.5
	1.6%	63.00a	37.0	54.13a	45.9
	3.2%	77.78c	22.2	58.38b	41.6

Means followed by the same letter within column are not significantly different at ($p<0.05$)

Considering the results with seeds of *S. vulgare* var. *technicum,* it was obvious that the negative effect on the germination process as a whole was not so strong in comparison with the *S. sudanense* seeds ($p<0.05$). Maximal inhibition of seed germination in comparison with the control was found at 3.2% extract of *Sorghum halepense* (L.) Pers., followed by the two highest concentrations of *Xanthium strumarium* L. extract. Least pronounced was the negative effect of the extract from *Aristolochia clematitis* L., where in all studied concentrations the germination was close to 80% and above. The extract of *Cirsium arvense* (L.) Scop. had the IR values in the range from 12.5% up to 41.6% and was quite similar to the extract of *Xanthium strumarium* L. with IR values in the range 12.5% - 45.9%. only in the experiment with *Sonchus arvensis* L. extract we could not observe some significant dynamics of the inhibitory effect related to the concentration variations. Germination % against the control varied from 62.50% to 87.50% and the IR was close to 37.5% in almost all cases (Table 1).

Seed germination is a critical phase of plant development (Ernst, 1998). This process begins with the uptake of water from the dry seed and its swelling and ends with the germination of the germ root through all the seed coatings (Bewley, 1997). Germination inhibition is one of the most studied effects of toxic exposure to heavy metals (Ernst, 1998; Sfaxi-Bousbih *et al.*, 2010), herbicides and biologically active substances, including allelochemicals (Kalinova *et al.*, 2012; Marinov-Serafimov *et al.*, 2017).

On the basis of their inhibition rate on the *S. sudanense* seed germination the five tested weed species could be ranked as follows:

1 group – $IR<29.99\%$: *Xanthium strumarium* L. (IR average=21.59%), *Sorghum halepense* (L.) Pers. (IR average=22.24%) and *Aristolochia clematitis* L. (IR average=22.24%)

2 group – $30\%<IR<49.99\%$: *Sonchus arvensis* L. (IR average=40.72%) and *Cirsium arvense* (L.) Scop. (IR average=40.72%)

On the basis of their inhibition rate on the *S. vulgare* var. *technicum* seed germination the five tested weed species could be ranked as follows:

1 group – $IR<29.99\%$: *Aristolochia clematitis* L. (IR average=19.46%), *Cirsium arvense* (L.) Scop. (IR average=27.77%) and *Xanthium strumarium* L. (IR average=28.48%)

2 group – $30\%<IR<49.99\%$: *Sorghum halepense* (L.) Pers. (IR average=31.25%) and *Sonchus arvensis* L. (IR average=31.25%).

This could be explained by the presence of glycoalkaloids, various phenolic acids (vanilla, syringe, ferulic, N-coumaric, etc.), condensed tannins, cyanoglycosides and hydrophobic p-benzoquinone, which are concentrated in the aboveground biomass of the studied weed species. Glycoalkaloids are known to have a highly toxic effect, with higher concentrations causing a lethal effect on germination of wheat seeds, while lower ones inhibit germination to varying degrees (Agarwal *et al.*, 2002). The differences found between reaction of two studied cultural Sorghum genotypes may also be due to differences in their allelopathic tolerance, since comparisons between them are made under the same conditions (Marinov-Serafimov *et al.*, 2017).

Conclusions

The results of this study are in good agreement with the previous findings that the alellopathic effect of weeds on seed germination varied according to the plant species (both weed and cultural) and the concentration applied. Both studied genotypes showed significantly high allelopathic tolerance to the invasive weed species – 68.1% for *Sorghum sudanense* (Piper) Stapf and 78.3% for *Sorghum vulgare* var. *technicum* Körn. This fact demonstrated that they are suitable for incorporation into various breeding programs as allelopathic tolerance donors. Reading of the allelopathic reaction is proved as fast and effective method for determining plant tolerance at different stages of the selection process.

References

Agarwal A., Gahlot A., Verma R., Rao P. (2002). Effects of weed extracts on seedling growth of same varieties of wheat. Journal of Environmental Biology, Vol. 23(1), pp. 19-23.

Alsaadawi I., Dayan F. (2009). Potentials and prospects of sorghum allelopathy in agroecosystems. Allelopathy Journal 24 (2), pp. 255-270.

Asghar M., Tanveer A., Nadeem A., Ali H. (2013). Comparative allelopathic potential of two aizoaceae weeds against germination of different crops. Pak. J. Weed Sci. Res., Vol. 19 (4), pp. 377-391.

Bewley D.J. (1997). Seed germination and dormancy. Plant Cell, Vol. 9, pp. 1055–1066.

Cheema Z.A., Iqbal M., Ahmad R. (2002) Response of wheat varieties and some rabi weeds to allelopathic of sorghum water extract. International Journal of Agriculture and Biology,

4, pp. 52–55.

Cheema Z.A., Khaliq A., Farooq M. (2008). Sorghum Allelopathy for Weed Management in Wheat. In: Zeng R.S., Mallik A.U., Luo S.M. (eds) Allelopathy in Sustainable Agriculture and Forestry. Springer, New York, NY.

Dafaallah A., El-Twom E. (2017). Allelopathic Effect of Eucalyptus (*Eucalyptus camaldulensis* Dehnh) Leaf on Seed Germination and Seedling Growth of some Poaceous Crops. International Journal of Forest, Animal and Fisheries Research (IJFAF), Vol. 1 (4), pp. 34-40.

Ernst W.H.O. (1998). Effects of heavy metals in plants at the cellular and organismic level ecotoxicology. In: Gerrit, S., Bernd, M. (Eds.), III. Bioaccumulation and Biological Effects of Chemicals. Wiley and Spektrum Akademischer Verlag, pp. 587–620.

Głąb L., Sowiński J., Bough R., Dayan F. (2017). Allelopathic Potential of Sorghum (Sorghum bicolor (L.) Moench) in Weed Control: A Comprehensive Review. Advances in Agronomy, Vol. 145, pp. 43-95.

Hamilton M., Russo R., Thurston R. (1977). Trimmed Spearman-Karber Method for Estimating Median Lethal Concentrations in Toxicity Bioassays. Environmental Science and Technology, Vol. 11 (77), pp. 14-719.

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

House L. (1985). A Guide to Sorghum Breeding. International Crops Research Institute for the Semiarid Tropics. 2nd Edition. ICRISAT, Patancheru, India.

Jabran, K. (2017). Sorghum allelopathy for weed control. In: K. Jabran, Manipulation of Allelopathic Crops for Weed Control. SpringerBriefs in Plant Science, Springer International Publishing AG, Switzerland. pp. 65-75. Jesudas A., Kingsley J., Ignacimuthu S. (2014). Sorgoleone from Sorghum bicolor as a Potent Bioherbicide. Research Journal of Recent Sciences, Vol. 3(ISC-2013), pp. 32-36.

Kalinova St., Hristova S., Glogova L. (2012). Effect of the weed infestation with *Sorghum halepense* on the yield and its structural elements in maize hybrid KN-613. Institute of Maize in Knezha, Bulgaria. Agricultural University Press, Plovdiv. [In Bulgarian]

Marinov-Serafimov P., Golubinova I. (2015). Sudan Grass Sensitivity to Some Herbicides. II. Productivity. Plant Science, Vol. LII (6), pp. 13-20.

Marinov-Serafimov P., Golubinova I., Kalinova S., Yanev M., Ilieva A. (2017). Allelopathic activity of some parasitic weeds. Bulgarian Journal of Agricultural Science, Vol. 23 (2), pp. 219–226.Oerke E.C. (2006). Crop losses to pests, Journal of Agricultural Sciences, Vol. 144, pp. 31-43.

Piotrowicz-Cieślak A.I., Adomas B., Nałecz-Jawecki G., Michalczyk D.J. (2010). Phytotoxicity of sulfamethazine soil pollutant to six legume plant species. Journal of Toxicology and Environmental Health Part A, Vol. 73(17-18), pp. 1220–1229.

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

Shahrokhi S., Bagheri A., Jamshidi S. (2011). Tolerance of Five Sorghum Cultivars to Different Concentrations of Common Lambsquarters (*Chenopodium album*) Leaf Aqueous Extracts, 2011 3rd International Conference on Chemical. Biological and Environmental Engineering IPCBEE vol.20 (2011) © (2011) IACSIT Press, Singapore, pp. 61-65.

Sfaxi-Bousbih A., Chaoui A., El Ferjani E. (2010). Cadmium impairs mineral and carbohydrate mobilization during the germination of bean seeds. Ecotoxicol. Environ. Saf., Vol. 73, pp. 1123–1129.

Undersander D., Lane W. (2003). Sorghum, sudan grasses and sorghum x sudan grass hybrids for forage. Available at: http://www.uwex.edu/ces/forage/pus/sorghum. Accessed on 15/07/2019.

Uzun F., Cigdem I. (2005). Forage sorghum and sorghum-sudan grass hubrids. Ondokuzmayis University, J. Agric. Fac., Vol. 20 (2), pp. 66-72.

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

Worthington M., Reberg-Horto, Ch. (2013). Breeding Cereal Crops for Enhanced Weed Suppression: Optimizing Allelopathy and Competitive Ability. Journal of Chemical Ecology, 39(2), pp. 213-231.