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Allelopathic effect of sunflower broomrape (*Orobanche cumana* Wallr.) on the development of sunflower (*Helianthus annuus* L.)

Shteliyana Kalinova[1*], Plamen Marinov-Serafimov[2], Irena Golubinova[2] and Valentina Encheva[3]

[1] *Agricultural University, 4000 Plovdiv, Bulgaria*
[2] *Agricultural Academy, Institute of Forage Crops, 5800 Pleven, Bulgaria*
[3] *Agricultural Academy, Dobroudja Agricultural Institute, 9520 General Toshevo, Bulgaria*
[*] *Corresponding author:* s_kalinova@yahoo.com

Abstract

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The allelopathic effect of dry biomass of sunflower broomrape (*Orobanche cumana* Wallr.) collected from ten regions of the Republic of Bulgaria was studied under laboratory conditions at the Institute for Forage Crops – Pleven. The allopathic effect of the experimental samples of sunflower broomrape on the seed germination and on the initial development of the sunflower, variety "Paredovik" was followed. It was found that the studied concentrations (8.0, 16.0 and 32.0% w/v) dry weed biomass of sunflower broomrape showed a stimulatory effect (from -0.7 to -55.3%) or an inhibitory effect on the germination of seeds (from 1.8 to 43.1%) and on the initial development (from 2.4 to 21.0%) of sunflower, variety "Paredovik". Depending on the alleopathic effect and the origin of the sunflower broomrape, they can be grouped in the following order: $P_{7(\text{Selanovtsi})}$ (86.9%) → $P_{9(\text{Radnevo})}$(83.0%) → $P_{4(\text{Kardam})}$ (73.4%) →$P_{5(\text{Tyulenovo})}$ (70.7%) →$P_{6\ (\text{Dyakovo})}$ (61.9%) →$P_{1\ (\text{Kardam})}$ (54.8%) →$P_{2(\text{DAI – Infection firld})}$ (50.6%) →$P_{3(\text{DAI – Experimental field})}$ (50.2%) →$P_{8(\text{Svishtov})}$ (46.0%) → $P_{10\ \text{Sozopol broomrape on } Artemisia\ maritima\ \text{L.}}$ (27.9%). The highest overall allelopathic potential (OAP = 0.6) conditionally was determined for sunflower broomrape originating $P_{2(\text{DAI – Infection field})}$ and $P_{3\ (\text{DAI – Experimental field}).}$ The lowest overall allelopathic potential (from 0.2 to 0.3) was determined for sunflower broomrape with the origin $P_{7\ (\text{Selanovtsi})}$ and $P_{9\ (\text{Radnevo})}$. This information can be explained by the genetic differences of the studied origins.

Keywords: allelopathic effect; broomrape; sunflower; inhibition

Introduction

Parasitic plants are among the most problematic pests of agricultural crops worldwide (Runyon et al., 2009; Blagojević et al., 2014).The technological approaches and effective means for control agains them are extremely limited, because the close physiological connection between the parasite plant and the host plant impedes the efficient control using traditional methods.

According to Macias et al. (2003), Reigosa et al. (2006) and Willis (2007), six families of parasitic weeds species (*Scrophulariaceae, Orobanchaceae, Santalaceae, Cuscutaceae, Viscaceae* and *Loranthaceae*) are of a great economic importance and cause the highest loss of agricultural production.

The parasitic weed sunflower broomrape (*Orobanche cumana* Wallr.) is one of the major limiting factors in sunflower production in the Republic of Bulgaria (Encheva and Shindrova, 1993; Shindrova, 2006; Venkov & Shindrova, 2000; Shindrova, 2006) and in many countries of the world (Miladinovic et al., 2012;Molinero-Ruiz et al., 2015; Pineda-Martos et al., 2014).The broomrape in sunflower has higher competitive ability than any other weed species its invasion leads to an adverse effect on the natural weeds in sunflower crops (Habimana et al.,2014). Due to the competitive nature, the parasitic species – sunflower broomrape causes significant losses, expressed on the one hand in the reduction of yield and on the other – in the deterioration of the quality of the production obtained (Shindrova et al., 1994; Perez-de-Luque et al., 2001).

Scientific researches in recent years are focused mainly on creating resistant varieties and hybrids and on the development of highly effective systems for integrated control against parasitic weed species. (Chittapur et al., 2001; Rubiales, 2012; Joel et al., 2013).

In this respect, the search for alternative means of weed control is very important (Chauhan & Mahajan, 2014). There is a growing interest to the allelopathy in agriculture at present.This phenomenon could provide perspective alternative methods of weed control and to help for reducing of the application of synthetic herbicides (Lopez-Raez, 2008).

Although allelopathy is under study by ecologists, chemists, soil scientists, agronomists, herbologists, biologists and plant physiologists the allelopathic interrelations in the „weed – plant" system are not fully understood, and in the case of „*host*plant–parasite" are extremely limited.

According to Jacobs and Rubery (1988), Serghini al. (2001), Perez-de-Luque et al. (2001), Qasem (2006), Matusova, et al. (2005) and Kalinova (2010) *Orobanche cumana* Wallr. has an alleopathic potential, probably due to the content of the allelochemicals (secondary metabolites – coumarins and others).

The discovery of main regularities in the allelopathic interaction in agrophytocenoses of *Helianthus annuus* L.and *Orobanche cumana* Wallr. appears to be a major element of the theoretical basis for sustainable plant-growing production.

The purpose of this study is to determine the alopeptic effect of some races *Orobanche cumana* Wallr. distributed in the main agricultural areas of the country on the germination and growth of *Helianthus annuus* L.

Materials and Methods

The study was conducted during the 2016-2018 period under laboratory conditions in the Institute of Forage Crops in Pleven, Bulgaria.

Two factors have been studied: Factor A – the location of the sunflower broomrape (*Orobanche cumana* Wallr.) (Table 1):a_1-Kardam; a_2 – Dobroudja Agricultural Institute, General Toshevo, Bulgaria (DAI) (Infection field); a_3 – Dobroudja Agricultural Institute, General Toshevo, Bulgaria (DAI) (Experimental field); a_4-Kardam; a_5-Tyulenovo; a_6 – Dyakovo; a_7 – Selanovtsi; a_8 – Svishtov; a_9 – Radnevo and a_{10} – Sozopol broomrape on *Artemisia maritima* L.Factor B – parasitic weed biomass concentration: b_1- 0.0% (control); b_2-8.0%; b_3-16.0% and b_4-32.0% w/v. Sampling of sunflower broomrape is consistent with the factor A in a growth stage BBCH 65-69 (Hess et al., 1997).

Table 1. The race composition of sunflower broomrape (*Orobanche cumana* Wallr.)

Origin		Year	Race
Code	Location		
P_1	Kardam	2016	H
P_2	Dobroudja Agricultural Institute, General Toshevo, Bulgaria (DAI) (Infection field)	2016	H
P_3	Dobroudja Agricultural Institute, General Toshevo, Bulgaria(DAI) (Experimental field)	2017	E
P_4	Kardam	2017	H
P_5	Tyulenovo	2017	H
P_6	Dyakovo	2017	H
P_7	Selanovtsi	2017	D
P_8	Svishtov	2017	E
P_9	Radnevo	2018	E
P_{10}	Sozopol broomrape on *Artemisia maritima* L .	2018	

To evaluate the allelopathyc potential of tested samples of sunflower broomrape (*Orobanche cumana* Wallr.) was used the adapted method called "Rhizosphere Soil Method" (RSM) of Fujii et al. (2005) under laboratory conditions. Parasitic weed biomass fromtested samples sunflower broomrape (*Orobanche cumana* Wallr.), according to factor B is placed in petri dishes (90 mm). On the parasitic weed biomass are pipetted 20 ml 0.8% strength agar supplemented with 1 ml/l thymol $C_{10}H_{14}O$, as a chemical preservative. (Marinov-Serafimov, Golubinova, 2015).The samples are stored for 72 h at 18 ± 2°C, after then ten numbers seeds of sunflower, variety. "Paredovik" are added. The prepared samples are placed in an incubator at 22 ± 2°C in the dark for five days. Distilled water is used for the control. Each variant is pledged in nine repetitions.

Effect assessment. For assessing the results of the experiments were used the following parameters.

Quantitative parameters. Number of germinated seeds in each treatment: percent of germination in each treatment (%).

Biometric parameters. Length of the root, stem and seedling, cm; fresh biomassin g per root, stem and seedling, g. Length was measured using graph paperand the weight was recorded on an analytical balance.

Statistical evaluation and calculated formulas.

Germination seeds (GS%) was determined by the Equation (1) prescribed according to ISTA (1985).

$$GS\% = \frac{\text{(Number of seed germinated)}}{\text{(Total number of seed plated).1,}} \quad (1)$$

Percent inhibition (IR) was determined by the equation, (2).

$$IR\% = \frac{C - T}{c} \times 100, \quad (2)$$

where *C* – characteristic in the control treatment; *T* – characteristics in each treatment;

The index of plant development (GI) was determined by the Equation, (3) (Gariglio et al., 2002).

$$GI = \left[\left(\frac{G}{G_0}\right).\left(\frac{L}{L_0}\right)\right].100 \quad (3)$$

where *G* – germinated seeds in each treatment, %; G_0 – germinated seeds in the control treatment, represpectively %; *L* – average length (cm) of seedlings in treatment transformed into percentage as against the control treatment; L_0 – average length (cm) of the seedlings in the control treatment taken as 100%;

Seedling vigor index (SVI) was determined by the equation (4) (Islam et al., 2009).

$$SVI = \left(\frac{S.G}{100}\right), \quad (4)$$

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 determined by the equation (5) (Nasr& Mansour, 2005):

$$CA = \frac{L_s}{L_r}, \quad (5)$$

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

Overall allelopathic potential (OAP) was determined by the equation (6) (Smith (2013):

$$OAP = \text{mean } (Ia + Ib)/100, \quad (6)$$

where *Ia*, a percent inhibition of the seedling growth at the lowest applied concentration of 8.0% w/v and *Ib* percent inhibition of the seedling growth at the highest applied concentration of 32.0% w/v, compared to the control variants.

A score between 0.0 and 1.0 was obtained and the data were ranked according to this score. A maximum score of 1.0 would indicate that the test samples sunflower broomrape (*Orobanche cumana* Wallr.) had totally inhibited growth, while a score of 0.0 would indicate that no allelopathic inhibition had occurred.

The percentage of seed germination was calculated after preliminary arcsin-transformation following the formula, Y = arcsin√(x%/100), forwarded by Hinkelmann&Kempthorne (1994).

The collected data were analyzed using the software Statgraphics Plus for Windows Ver. 2.1 and Statistica Ver. 10.

Results and Discussion

The above ground dry biomass of samples sunflower broomrape (*Orobanche cumana*) from different regions of the Republic of Bulgaria manifests an inhibitory effect (IR from 5.0 to 55.2% w/v) on the seed germination of sunflower (*H.annuus*) (Table 2).

By increasing the content of the parasitic weed biomass (from 16.0 to 32.0% w/v), the germinating seeds oftest plant –*H.annuus* decreased disproportionately compared to the control variant. The differences being statistically significantly reduced at P = 0.05.

An exception to the described dependence was found in variant P7 at the lowest concentration (8.0% w/v). The differences being statistically unproven at P = 0.05 compared to the control variant.

This relationship can be explained by the presence of allelochemicals (secondary metabolite, coumarins and others) in the studied samples from sunflower broomrape (Perez-de-Luque et al., 2001).

Depending on the origin and race of the tested sunflower broomrapes samples (Table 1), the degree of inhibition of *H. annuus* (table.2) germination seeds can be arranged in the following order: P_7 ($IR_{average}$17.1%)→P_6($IR_{average}$17.9%)→P_5 ($IR_{average}$20.7%)→P_8 ($IR_{average}$26.8%)→P_4 ($IR_{average}$28.0%)→$P_1$and P_2($IR_{average}$30.2%)→P_{10} ($IR_{average}$30.6%)→P_9 ($IR_{average}$30.9%)→P_3($IR_{average}$43.1%).

The data of the biometric measurements of the length of the root, stem and seedling length growth (cm) give possibility for objective estimation of the differences at the initial growth and development stages of the *H.annuus* depending on the type and applied concentration of the tested parasitic weed biomass from different tested sunflower broomrape (*O.cumana*) (Table 3).

The degree of reducing the length of the germ of *Helianthus annuus* L. is in the range of 5.5 to 68.5%. The most severe is the degree of inhibition of the root (from 2.9 to 71.5%), and relatively weaker of the stem (from 1.6 to 64.4%) compared to the control with distilled water (Table 3).

Concerning concentration dependencies, it is evident that with increase content parasitic weed biomass (from 16.0 to

Table 2. Allelopathic effect of dry above ground biomass of different races *Orobanche cumana* Wallr. on seeds germination of sunflower variety Peredovik

Treatment	Origin		Concentration % w/v	Germination seeds, %	Germination in relative to the control variant, %	IR
	Code	Location				
1		Control	0.0	80.78d	100.00	0.0
2	P_1	Kardam	8.0	61.17a-c	75.72	24.3
			16.0	53.78a-c	66.57	33.4
			32.0	54.22a-c	67.12	32.9
3	P_2	DAI (Infection field)	8.0	64.18bc	79.45	20.5
			16.0	57.10ab	70.69	29.3
			32.0	47.88ab	59.28	40.7
4	P_3	DAI (Experimental field)	8.0	53.78ab	66.57	33.4
			16.0	47.88ab	59.28	40.7
			32.0	36.22a	44.84	55.2
5	P_4	Kardam	8.0	63.43b-c	78.53	21.5
			16.0	60.11ab	74.41	25.6
			32.0	50.89ab	63.00	37.0
6	P_5	Tyulenovo	8.0	76.72c-d	94.97	5.0
			16.0	70.38b-c	87.13	12.9
			32.0	45.00ab	55.71	44.3
7	P_6	Dyakovo	8.0	70.38bc	87.13	12.9
			16	67.50bc	83.56	16.4
			32	61.17a-c	75.72	24.3
8	P_7	Selanovtsi	8.0	80.78d	100.00	0.0
			16.0	60.1a-c	74.41	25.6
			32.0	60.11a-c	74.41	25.6
9	P_8	Svishtov	8.0	60.11a-c	74.41	25.6
			16.0	60.11a-c	74.41	25.6
			32.0	57.10ab	70.69	29.3
10	P_9	Radnevo	8.0	61.17a-c	75.72	24.3
			16.0	55.40ab	68.58	31.4
			32.0	50.89ab	63.00	37.0
11	P_{10}	Sozopol broomrape on *Artemisia maritima*L .	8.0	56.79ab	70.30	29.7
			16.0	57.10ab	70.69	29.3
			32.0	54.22ab	67.12	32.9

Legend: Means with different letters differ at P < 0.05 level of probability by LSD test; IR – percent inhibitions; DAI – Dobroudja Agricultural Institute, General Toshevo, Bulgaria

32.0% w/v), the length of the seedlings decreased disproportionately in all treatments of *H.annuus*, compared to the control treatment. The differences are statistically proven reduced at P = 0.05.

The lowest applied concentration (8.0% w/v) of parasitic weed biomass from all tested samples of sunflower broomrape has from relatively weak inhibitory to weak stimulating effect on the growth of sunflower seedling.The differences are statistically insignificant at P = 0.05 (Table 3).

An exception is found at code P_9 where in all tested concentrations of parasitic weed biomas, the differences in the length of the root, shoot and seedling of the test variety Peredovikare statistically insignificant. At code P_2 and P_{10} the studied indicators are statistically significant decrease at P = 0.05 compared to the control variant (Table 1 and Table 3).

The accumulation of fresh biomass in g for one root, one stem and one seedlingat the early growth stages of test plant – sunflower depends of the same factors (races of sunflower broomrape and applied concentrations) and follows the established dependencies on the growth of root, shoot and seedlihg of lengthwith this difference, that they are less pronounced (Table 1 and Table 4).

Table 3. Allelopathic effect of dry above ground biomass of different races of *Orobanche cumana* Wallr. on the seedling growth of sunflower variety Peredovik

Treatment	Origin		Concentra-tion % w/v root	Length, cm					
	Code	Location		IR	stem	IR	seedling	IR	
1		Control	0.0	9.78j-m	0.0	4.50m	0.0	14.28i-j	0.0
2	P_1	Kardam	8.0	8.25h-k	15.6	4.58m	-1.8	12.83h-j	10.2
			16.0	6.21e-g	36.5	2.79d-h	71.5	9.00e-g	37.0
			32.0	5.88ef	39.9	2.94b-i	69.9	8.81ef	38.3
3	P_2	DAI (Infection field)	8.0	6.14e-g	37.2	2.36a-e	75.9	8.50b-e	40.5
			16.0	5.13c-e	47.5	2.31a-e	76.4	7.44b-f	47.9
			32.0	5.25c-f	46.3	2.83d-i	71.1	8.08c-f	43.4
4	P_3	DAI (Experimental field)	8.0	6.57e-h	32.8	2.37a-e	75.8	8.94e-g	37.4
			16.0	8.00g-j	18.2	3.50i-k	64.2	11.50gh	19.5
			32.0	5.20c-f	46.8	3.00d-g	69.3	8.20c-f	42.6
5	P_4	Kardam	8.0	10.38m	-6.1	2.76d-g	71.8	13.14h-j	8.0
			16.0	9.31j-m	4.8	3.44g-k	64.8	12.75h-i	10.7
			32.0	7.07f-i	27.7	3.00d-k	69.3	10.07f-h	29.5
6	P_5	Tyulenovo	8.0	10.19lm	-4.2	2.29d-e	76.6	12.48 h-i	12.6
			16.0	4.20a-d	57.1	2.00a-c	79.6	6.20a-c	56.6
			32.0	2.90ab	70.3	1.60a	83.6	4.50a	68.5
7	P_6	Dyakovo	8.0	9.50j-m	2.9	2.92d-j	70.1	12.42g-i	13.0
			16.0	8.75i-m	10.5	2.58d-e	73.6	11.33g-i	20.7
			32.0	3.90a-c	60.1	3.45h-k	64.7	7.35-e	48.5
8	P_7	Selanovtsi	8.0	10.00k-m	-2.2	3.50a-e	64.2	13.50c-f	5.5
			16.0	9.38j-m	4.1	3.75i-k	61.7	13.13h-i	8.1
			32.0	5.72c-f	41.5	2.33de	76.2	8.06e-g	43.6
9	P_8	Svishtov	8.0	8.57i-l	12.4	4.43lm	54.7	13.00h-j	9.0
			16.0	2.79a	71.5	3.71k-m	62.1	6.50a-d	54.5
			32.0	2.81a	71.3	2.69c-e	72.5	5.50ab	61.5
10	P_9	Radnevo	8.0	10.44i-l	-6.7	4.75m	51.4	15.19h-j	-6.4
			16.0	8.50m	13.1	4.58m	53.2	13.08g	8.4
			32.0	8.25h-k	15.6	3.67j-m	62.5	11.92gh	16.5
11	P_{10}	Sozopol broomrape on *Artemisia maritime* L .	8.0	5.60d-f	42.7	3.25h-l	66.8	8.85b-f	38.0
			16.0	5.79d-f	40.8	1.93a	80.3	7.70ef	46.1
			32.0	4.86b-e	50.3	2.71c-f	72.3	7.57b-e	47.0

Legend: Means with different letters differ at $P < 0.05$ level of probability by LSD test; IR – percent inhibitions; DAI – Dobroudja Agricultural Institute, General Toshevo, Bulgaria

Therefore, the observed differences at tested samples of *O.cumana* in terms of their allelopathic potential versus test plants *H. annuus* can be probably explained by biochemical differences, because the comparisons between them are performed at equal conditions.

The variati on analysis to determine the influence of the studied factos (η_2) on the seed germination and on the initial growth of *H.annuus*s shows that the largest share of the total variation was due to Factor A (η_2 from 11.8 to 34.1) – the races of *O.cumana*. The applied concentrations of parasit weed biomas (Factor B) are factors with a significant impact on the variation of phytotoxicity (η_2 from 3.7 to 21.4).The variants due to the "species sunflower broomrape – applied concentration" relationship are in the range from η_2 11.8 to $\eta_2$39.8 (Figure 1).

The obtained experimental data confirmed the results of Ruiyu et al.(2007), Ali et al. (2013), Takemura et al. (2013), according to them the effect of the allelochemicals is manifested already during the seed germination, but it is more pronounced during the growth and accumulation biomass of seedlings of the test-plants.

Table 4. Allelopathic effect of dry above ground biomass of different races *Orobanche cumana* Wallr. on the dynamics of the accumulation of fresh biomass of sunflower seedlings variety Peredovik

Treat ment	Origin		Concentra-tion, % w/v	Fresh biomass, g					
	Code	Location		root	IR	stem	IR	seedling	IR
1		Control	0.0	0.115i-k	0.0	0.340mn	0.0	0.455mn	0.0
2	P_1	Kardam	8.0	0.128k-n	-11.3	0.365o	-7.4	0.493q	10.2
			16.0	0.089de	22.6	0.319kl	6.2	0.408jk	37.0
			32.0	0.094e-g	18.3	0.263de	22.6	0.357g	38.3
3	P_2	DAI (Infection field)	8.0	0.086de	25.2	0.323e	5.0	0.409jk	40.5
			16.0	0.089de	22.6	0.307i-k	9.7	0.396ij	47.9
			32.0	0.085de	26.1	0.295ij	13.2	0.380h	43.4
4	P_3	DAI (Experimental field)	8.0	0.136mn	-18.3	0.323e	5.0	0.459no	37.4
			16.0	0.105g-i	8.7	0.307jk	9.7	0.411kl	19.5
			32.0	0.085de	26.1	0.236c	30.6	0.321e	42.6
5	P_4	Kardam	8.0	0.167o	-45.2	0.279f-h	17.9	0.446mn	8.0
			16.0	0.123g-n	-7.0	0.285f-i	16.2	0.408jk	10.7
			32.0	0.078cd	32.2	0.275e-g	19.1	0.353fi	29.5
6	P_5	Tyulenovo	8.0	0.157o	-36.5	0.285f-i	16.2	0.443m	12.6
			16.0	0.061b	47.0	0.215b	36.8	0.277c	56.6
			32.0	0.045a	60.9	0.181a	46.8	0.225a	68.5
7	P_6	Dyakovo	8.0	0.098e-h	14.8	0.288g-i	15.3	0.386hi	13.0
			16.0	0.109g-i	5.2	0.279fg	17.9	0.388hi	20.7
			32.0	0.045a	60.9	0.205b	39.7	0.250b	48.5
8	P_7	Selanovtsi	8.0	0.128k-n	-11.3	0.349n	-2.6	0.477p	8.1
			16.0	0.120g-n	-4.3	0.338mn	0.6	0.458no	43.6
			32.0	0.090de	21.7	0.249cd	26.8	0.339f	5.5
9	P_8	Svishtov	8.0	0.094e-g	18.3	0.330lm	2.9	0.424e	9.0
			16.0	0.066bc	42.6	0.293h-j	13.8	0.359j	54.5
			32.0	0.065bc	43.5	0.239c	29.7	0.303d	61.5
10	P_9	Radnevo	8.0	0.120j-l	-4.3	0.326lm	4.1	0.446mn	-6.4
			16.0	0.140mn	-21.7	0.345n	-1.5	0.485pq	8.4
			32.0	0.125f-i	-8.7	0.392p	-15.3	0.517r	16.5
11	P_{10}	Sozopol broom-rape on *Artemisia maritime* L .	8.0	0.104g-i	9.6	0.271ef	20.3	0.375h	38.0
			16.0	0.133mn	-15.7	0.338mn	0.6	0.471op	46.1
			32.0	0.079a	31.3	0.307j-k	9.7	0.386hi	47.0

Legend: Means with different letters differ at P < 0.05 level of probability by LSD test; IR – percent inhibitions; DAI – Dobroudja Agricultural Institute, General Toshevo, Bulgaria

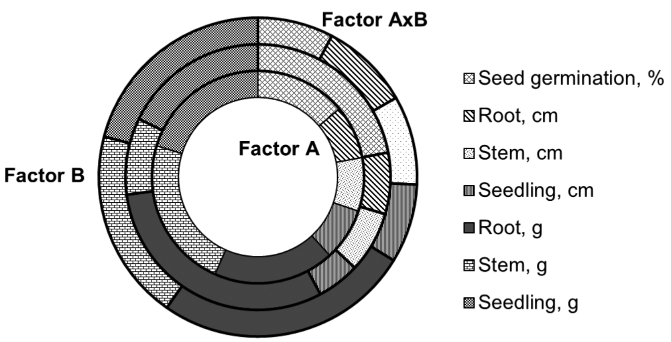

Fig. 1. Projection of influence of factors on the factorial plane

Table 5. Developmental index in the early stages of the development of sunflower (*Helianthus annuus* L.) in dependence on the sunflower broomrape (*Orobanche cumana* Wallr.)

Treat ment	Origin		Concen-tration, % w/v	*CA*	*SVI*	*GI*	*OAP*		
	Code	Location					Germina-tion seeds	Seedling lenght	Fresh biomass on sunflower seedling
1		Control	0.0	2.2	11.5	100.0	–	–	–
2	P_1	Kardam	8.0	1.8	7.9	72.2	0.6	0.5	0.1
			16.0	2.2	4.8	46.5			
			32.0	2.0	4.8	45.7			
3	P_2	DAI (Infectious disease)	8.0	2.6	5.5	49.5	0.6	0.8	0.3
			16.0	2.2	4.2	49.7			
			32.0	1.9	3.9	52.5			
4	P_3	DAI (Experimen-tal field)	8.0	2.3	6.2	62.3	0.9	0.6	0.3
			16.0	2.8	4.3	55.1			
			32.0	1.7	3.0	33.2			
5	P_4	Kardam	8.0	3.8	8.3	75.9	0.6	0.4	0.2
			16.0	2.7	7.7	70.9			
			32.0	2.4	5.1	73.3			
6	P_5	Tyulenovo	8.0	4.5	9.6	144.4	0.5	0.8	0.5
			16.0	2.1	4.4	46.9			
			32.0	1.8	2.0	20.7			
7	P_6	Dyakovo	8.0	3.3	8.7	77.5	0.3	0.6	0.6
			16.0	3.4	7.7	63.8			
			32.0	1.1	4.5	44.4			
8	P_7	Selanovtsi	8.0	2.9	10.9	85.7	0.3	0.5	0.2
			16.0	2.5	7.9	84.3			
			32.0	2.5	4.8	90.8			
9	P_8	Svishtov	8.0	1.9	7.8	72.3	0.5	0.7	0.4
			16.0	0.8	3.9	36.2			
			32.0	1.0	3.1	29.5			
10	P_9	Radnevo	8.0	2.2	9.3	73.6	0.6	0.1	-0.1
			16.0	1.9	7.2	100.7			
			32.0	2.3	6.1	74.7			
11	P_{10}	Sozopol broomrape on *Artemisia maritime* L .	8.0	1.8	5.1	53.8	0.6	0.9	0.3
			16.0	2.9	4.3	16.8			
			32.0	1.8	4.1	13.2			

Legend: CA – Coefficient of allometry*; SVI* – Seedling vigor index *GI* – index of plant development; OAP – Overall allelopathic potential; *DAI – Dobroudja Agricultural Institute, General Toshevo, Bulgaria*.

The obtained results were analogous when determining seedling vigor index (SVI) and alumetry coefficient (CA) of sunflower (*H. annuus*) (Table 5).Tested sunflower broomrapes samples provoked an inhibitory effect on sunflower vitality (from 5.2 to 82.6%) and reduces (from 0.5 to 2.8 times) alumetry coefficient (CA), as compared to the control variant.

The index of plant development (*GI*) dependsof the same factors and follows the observed relationship pattern with regard to laboratory seed germination, and accumulation of fresh biomass and growth of seedling of test plants – *H. annuus* (Table 5).

The analyses indicated that the studied races sunflower broomrape (*O. cumana*) shows an allelopathic effect – *GI* varing from 27.9 to 14.4% and depending of the applied concentrations.It can be arranged in the following order: $P_{7(\text{Selanovtsi})}$ (86.9%) → $P_{9(\text{Radnevo})}$ (83.0%) → $P_{4(\text{Kardam})}$ (73.4%) →$P_{5(\text{Tyulenovo})}$ (70.7%) →$P_{6\ (\text{Dyakovo})}$ (61.9%) →$P_{1\ (\text{Kardam})}$ (54.8%) →$P_{2(\text{DAI-Infection field})}$ (50.6%) →$P_{3(\text{DAI-Experimental field})}$ (50.2%) →$P_{8(\text{Svishtov})}$ (46.0%) → $P_{10(\text{Sozopol})}$ (27.9%).

The overall allelopathic potential (OAP) of the studiedraces of *O.cumana* is in the range of -0.1 to 0.9.

With the highest overall allelopathic potential (OAP) can determine conditionally the races sunflower broomrape P_2 (DAI-Infection field), P_5 (Tyulenovo), P_8 (Svishtov) и P_{10} (Sozopol), with a value from 0.7 to 0.9 OAP. With the lowest OAP- 0.1 is P_9 (Radnevo).

Conclusions

Dry weed biomass of sunflower broomrape (*Orobanche cumana* Wallr.) at concentrations of 8.0, 16.0 and 32.0% w/v has a stimulatory effect (from -0.7 to -55.3%) or an inhibitory effect on the germination of seeds (from 1.8 to 43.1%) andon the initial development (from 2.4 to 21.0%) of sunflower variety Peredovik

Depending on the alleopathic effect and the origin of the sunflower broomrape (*Orobanche cumana* Wallr.), they can be grouped in the following order: $P_{7(\text{Selanovtsi})}$ (86.9%) → $P_{9(\text{Radnevo})}$ (83.0%) → $P_{4(\text{Kardam})}$ (73.4%) →$P_{5(\text{Tyulenovo})}$ (70.7%) →$P_{6\ (\text{Dyakovo})}$ (61.9%) →$P_{1\ (\text{Kardam})}$ (54.8%) →$P_{2(\text{DAI-Infection field})}$ (50.6%) →$P_{3(\text{DAI-Experimental field})}$ (50.2%) →$P_{8(\text{Svishtov})}$ (46.0%) → $P_{10(\text{Sozopol})}$ (27.9%).

The highest overall allelopathic potential (OAP = 0.6) can be conditionally determined sunflower broomrape originating $P_{2(\text{DAI-Infection field})}$ 2016), $P_{3(\text{DAI-Experimental field})}$ and $P_{6(\text{Dyakovo})}$ and with the lowest (OAP – from 0.2 to 0.3) originating from $P_{7(\text{Selanovtsi})}$ and $P_{9(\text{Radnevo})}$.This fact can be explained by the genetic differences of the studied origins.

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