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ALLELOPATHIC ACTIVITY OF SOME PARASITIC WEEDS

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Abstract

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Allelopathic activity of *Cuscuta epithymum* L. (CVCEY), *Cuscuta campestris* Yuncker (CVCCA), *Phelipanche ramosa* (L.) *Pomel* (ORARA), *Phelipanche mutelii* (Schultz) Reuter (ORARM) and *Phelipanche* spp. (PHESS) on germination and initial development of test plants of *Lactuca sativa* L. cultivar "Great Lakes" was studied under laboratory conditions. It was found, that water exracts of the researched parasitic weed species in concentrations 0.4, 0.8, 1.6, 3.2, 6.4 and 12.8% w/v have a relatively high inhibitory effect on the seed germination of the test plant. The inhibiting rate of parasitic weed species from family *Convolvulaceae* ranges from 6.24 to 100.0% and for the species of family *Orobanchaceae* from 42.1 to 100.0%. Parasitic weed species from family *Orobanchaceae* [*Ph. ramosa*, *Ph. mutelii* and *Phelipanche* spp.] showed a considerably stronger allelopathic effect ($GI_{average}$ 17.9), as compared with the applied concentrations of water exracts of species from family *Convolvulaceae* [*C. epithymum* and *C. campestris*] ($GI_{average}$ 22.7).

Key words: dodder, broomrape, allelopathic potential*, Lactuca sativa* L.

Introduction

A major problem with parasitic weed species is their high biological and ecological plasticity, which facilitates their rapid adaptation and dissemination (Parker, 2009; Kubiszewski and Cleveland, 2012; Parker, 2012).

The parasitic weed species is common agricultural weed throughout the world, causing reductions in yield of many crops and if infestation is heavly, causes the death of host (Salgude et al., 2015).

The integrated pest management (IPM) is recognized as the preferred strategy for the weed control (Kubiszewski and Cleveland, 2012; Joel et al., 2013). IPM typically involves a reduction in the reliance on chemical pesticides, including herbicides (Hatcher and Melander, 2003).

The advantages are in its complexity, the more effective destruction of parasitic weed species and lower risk of environmental pollution with herbicides.

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

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

Biosynthesized herbicides (isolated from plants with allelopathic potential) are readily biodegradable. It is believed that they are much safer than synthesized herbicides (Belz, 2007; Hassannejad and Ghafari, 2013).

Although allelopathy is under study by ecologists, chemists, soil scientists, agronomists, herbologists, biologists, plant physiologists and molecular biologists the complicated interrelations in the "weed – plant" system are not fully understood.

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According to Inderjit et al. (2011) and Othman et al. (2012) plant allelopathy is a breakthrough in the field of agricultural science. Allelopathy serves as secondary metabolites, which result from the adaptation process of plants.

The interaction between weeds and crops is simultaneous and/or sequential with a direct or indirect effect of one plant species to another, through the synthesis of various chemical compounds – allelochemicals that are released into the environment having inhibiting and/or stimulating effect on seed germination and the initial development of a number of weeds and crops even in low concentrations (Jafari and Abdollahi, 2014; Shehata, 2014; Ravlić et al., 2015; Petrova et al., 2015).

Seed germination is a key phase for parasitic plant development and infestation, for the management of these parasitic weed species has been to use natural metabolites produced by plants as seed germination inhibitors (Benvenuti, 2005; Feng-lan et al., 2012; Ebrahimi and Hassannejad, 2015).

Reports a number of authors (Fernández-Aparicio et al., 2013; Seyyedi et al., 2013; Chai et al., 2015; Ebrahimi and Hassannejad, 2015) concerning the allelopathic effects of the parasitic weed species on the germination of the test plants under laboratory conditions were sporadic and inconsistent.

Objective of present study was to determine the probable allelopathic effect of parasitic weed species of the family *Orobanchaceae* and *Convolvulaceae* on germination and growth of test plants of *Lactuca sativa* L. cultivar "Great Lakes".

Materials and Methods

The study was carried out under laboratory conditions at the Institute of Forage Crops in Pleven, Bulgaria.

It was studied two factors: Factor A – parasitic weed species: a_1 – *Cuscuta epithymum* L. (CVCEY); a_2 – *Cuscuta campestris* Yuncker (CVCCA); a_3 – *Phelipanche ramosa* L. (ORARA); a_4 – *Phelipanche mutelii* (Schultz) Reuter (ORARM); a_4 – *Phelipanche* spp. (PHESS) (Table 1) and Factor B – concentration*:* b_1 – Control; b_2– 0.4% w/v; b_3–0.8% w/v; b_4– 1.6% w/v; b_5 – 3.2% w/v; b_6 – 6.4 % w/v and b_7 – 12.8% w/v.

Collection and preparation of plant material

The biomass from plant samples of species *Ph. ramosa*, *Ph. mutelii* and *Phelipanche* spp. was collected from tobacco fields in several regions of the Southeast Bulgaria. The biomass from plant samples of species *C. epithymum* and *C. campestris* was collected in a natural environment of weed infestation in the region of the Institute of Forage Crops, Pleven at BBCH 61 (Hess et al., 1997).

No separated aboveground biomass of available parasitic weed species was chopped together to the length of 0.5-3.0 cm, drying to a constant dry weight at 50 ± 5°C was grind in grinder Retsch SM – 1 at a sieve with size of 1.0 mm.

Bioassay techniques

The dray weed biomass according to the factor A and B was added in the Petri dishes (diameter 90 mm) with 20 ml 0.75% agar. The samples are stored for 72 h at 18 ± 2°C. Then five number seeds of *Lactuca sativa* L. cultivar "Great Lakes" ware place, according to the adapted method of Fujii et al. (2003), Takemura et al. (2013). The so prepared samples were put in incubator at 22 ± 2°C for five days, under dark conditions. Distilled water was used as a control. Each treatment consisted of ten replicates including the control treatment.

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 biomass in g per seedling, g. Length was measured using graph paper and the weight was recorded on an analytical balance.

Biochemical analysis of weed biomass

Nitrogen (N) (Kjeldahl); calcium (Ca) – complexometric (Sandev, 1979); phosphorus (P) – colorimetric (Sandev, 1979); crude fiber (in Veendam method); TMC – total mineral content (ash) was determined after burned at 500°C; water-soluble sugars (Ermakov et al., 1987); total phenols

Table 1
Plant taxonomy of experimental parasitic weed species and symbol from EPPO codes database

Plant taxonomy					
Class	EPPO Code	Family	EPPO Code	Species	EPPO Code
Angiospermae	ANGC	*Convolvulaceae*	COVF	*Cuscuta epithymum* L.	CVCEY
Angiospermae	ANGC	*Convolvulaceae*	COVF	*Cuscuta campestris*Yuncker	CVCCA
Angiospermae	ANGC	*Orobanchaceae*	ORAF	*Phelipanche ramosa* (L.) Pomel	ORARA
Angiospermae	ANGC	*Orobanchaceae*	ORAF	*Phelipanche mutelii* (Schultz) Reuter	ORARM
Angiospermae	ANGC	*Orobanchaceae*	ORAF	*Phelipanche* spp.	PHESS

(Swain and Hillis, 1959); condensed tannins (Terrill et al. 1992).

Statistical evaluation and calculated formulas

Dynamic Development Index (*DDI*) was determined by the Equation (1).

$$DDI = \left\{ \frac{\text{tlog}^2}{\log b - \log a} \right\}, \quad (1)$$

where *a* and *b* – germinated seeds (%), length (cm) and/or fresh biomass (g) of seedlings respectively in the control and in each treatment; *t* – duration days;

Response index (*RI*) was determined by the Equation (2) (Williamson and Richardson, 1988).

$$RI = \frac{T}{C} - 1, \quad (2)$$

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

Growth rate and accumulation of fresh biomass of the seedling was determined using an adapted formula by Dauta et al. (1990), Equation (3).

$$\mu = \left\{ \frac{\ln N_t - \ln N_o}{t} \right\}, \quad (3)$$

where N_t – length (cm) or fresh biomass (g) of the seedlings in each treatment; N_o – length (cm) or fresh biomass (g) of the seedlings in control treatment; *t* – duration in days;

Rate of emergence ($GR_{\%}$) was determined by the Equation (4).

$$GR_{\%} = \left(1 - \frac{(N_t - C_n)}{(N_c)}\right).100, \quad (4)$$

where N_t – germinated seeds in each treatment (%); N_c – germinated seeds in the control treatment (%); C_n – concentration, respectively %;

The index of plant development (*GI*) was determined by the Equation (5) (Gariglio et al., 2002).

$$GI = \left[\left(\frac{G}{G_o}\right) \cdot \left(\frac{L}{L_o}\right)\right].100, \quad (5)$$

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%;

The percentage of germinated seeds in each treatment was previously transformed $Y = acrsin\sqrt{(x\%/100)}$ (Anant, 1996). The effective concentrations required to induce half-maximal inhibition of growth (LC_{50}) and 95% confidence intervals were calculated by the Hamilton, Russo and Thurston (1977). Measurements of the pH values were done using a Digitales PH-Meter PH -100 ATC. The collected data were analyzed using by the software Statgraphics Plus for Windows Ver. 2.1 and STATISTICA Ver. 10.

Results and Discussion

The percentage germination of the test plants – *Lactuca sativa* L. showed variation with respect to the applied concentration of parasitic weed species of Dodder [*C. epitium* and *C. campestris*] and Broomrape [*Ph. ramosa, Ph. mutelii* and *Phelipanche* spp.] (Table 1 and 2).

The applied concentration from parasitic weed species of Dodder [*C. epitium* and *C. campestris*] and Broomrape [*Ph. ramosa, Ph. mutelii* and *Phelipanche spp.*] showed an relative high inhibitory effect on the seed germination of test plants – *L. sativa*. The inhibiting rate of parasitic weed species for family *Convolvulaceae* ranges from 6.24 to 100.0% and for the family *Orobanchaceae* from 42.1 to 100.0%.

With the increase of weed biomass content, the germinated seed percentage decreased disproportionately in all treatments, as compared to the control variant, the differences being statistically significantly smaller at $P < 0.05$. However, parasitic plant species indicate significant effect on *L. sativa* seed germination percentage and emergence rate.

Development index and the coefficients of depression on the germination of *L. sativa* depending on factors studied were established values of *DDI* which decrease from 1.9 to 31.8, while *RI* and μ has increased from 1.5 to 31.6 times (Table 3).

Depending on the weed species, the rate of emergence ($GR_{\%}$) on seed germination of the *L. sativa* could be conventionally grouped in three groups (Table 2 and Table 3).

First group (seed germination inhibition up to 50%): treatment from dry biomass of *C. epitium.* Second group (seed germination inhibition up 80%) including treatment from dry biomass of [*Ph. ramosa, C. campestris* and *Phelipanche* spp.]. Third group (seed germination inhibition up to 80%) – extracts from dry biomass of *Ph. mutelii.*

Analogous results have been obtained during of determining the LC_{50} ($P < 0.05$) for germination of seeds *L. sativa*, depending on the inhibitory effect of the parasitic weed species. They can be arranged in the following order: *C. epithymum* [2.23% w/v (1.91-2.60% w/v)] → *Ph. ramosa* [1.03% w/v (0.91-1.17% w/v)] → *C. campestris* [1.00% w/v (0.79 – 1.27% w/v)] → *Ph. mutelii* [0.57% w/v (0.31 – 1.02% w/v)] → *Phelipanche* spp. [0.57% w/v (0.31 – 1.02% w/v)] (Table 2).

The observed differences in test species can be explained by allelopathic potential differences of the parasitic weeds,

Table 2
Allelopathic effect of Dodder (*C. epitium* and *C. campestris*) on germination and initial development of *Lactuca sativa* L. under laboratory conditions

Variants		Parameters					LC_{50}
Concentration, % w/v		Germination, % root	Length, cm			Weight, g	
			stem	seedling	seedling		
Control		72.00^{d}	2.49^{c}	2.16^{d}	4.65^{d}	0.0084^{c}	2.23 (1.91-2.60)
C. epithymum	0.4	67.51^{cd}	1.40^{c}	1.60^{c}	3.00^{c}	0.0077^{bc}	
	0.8	50.90^{bc}	1.01^{bc}	1.60^{c}	2.61^{c}	0.0073^{bc}	
	1.6	42.12^{b}	0.84^{ab}	1.63^{cd}	2.47^{c}	0.0068^{bc}	
	3.2	39.23^{b}	0.94^{abc}	1.44^{bc}	2.38^{bc}	0.0063^{b}	
	6.4	9.22^{a}	0.30^{ab}	0.50^{ab}	0.80^{ab}	0.0019^{a}	
	12.8	9.22^{a}	0.20^{ab}	0.30^{a}	0.50^{a}	0.0023^{a}	
Control		72.00^{d}	2.49^{c}	2.16^{c}	4.65^{c}	0.0084^{c}	1.00 (0.79 – 1.27)
C. campestris	0.4	50.90^{c}	1.05^{b}	1.10^{b}	2.15^{b}	0.0052^{b}	
	0.8	36.22^{c}	0.87^{ab}	1.07^{b}	1.94^{b}	0.0042^{b}	
	1.6	33.21^{bc}	0.65^{ab}	0.83^{ab}	1.48^{ab}	0.0033^{b}	
	3.2	13.29^{ab}	0.50^{ab}	0.50^{ab}	1.00^{ab}	0.0013^{a}	
	6.4	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.0000^{a}	
	12.8	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.0000^{a}	
Control		72.00^{d}	2.49^{c}	2.16^{d}	4.65^{d}	0.0084^{c}	1.03 (0.91- 1.17)
Ph. ramosa	0.4	67.50c	1.61^{c}	1.40^{b}	3.01^{c}	0.0084^{d}	
	0.8	29.89b	1.08^{bc}	1.03^{ab}	2.11^{bc}	0.0067^{cd}	
	1.6	26.57b	0.50^{ab}	0.50^{ab}	1.00^{ab}	0.0050^{bc}	
	3.2	13.29ab	0.50^{ab}	0.50^{ab}	1.00^{ab}	0.0025^{ab}	
	6.4	0.00a	0.00^{a}	0.00^{a}	0.00^{a}	0.0000^{a}	
	12.8	0.00a	0.00^{a}	0.00^{a}	0.00^{a}	0.0000^{a}	
Control		72.00^{d}	2.49^{c}	2.16^{d}	4.65^{d}	0.0084^{c}	0.57 (0.31 – 1.02)
Ph. mutelii	0.4	39.23^{c}	1.25^{b}	1.06^{b}	2.31^{b}	0.0067^{bc}	
	0.8	33.21^{bc}	0.50^{a}	1.00^{b}	1.50^{ab}	0.0063^{b}	
	1.6	16.61^{ab}	0.43^{a}	0.50^{ab}	0.93^{ab}	0.0017^{a}	
	3.2	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.0000^{a}	
	6.4	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.0000^{a}	
	12.8	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.0000^{a}	
Control		72.00^{c}	2.49^{c}	2.16^{c}	4.65^{c}	0.0084^{d}	0.57 (0.31 – 1.02
Phelipanche spp.	0.4	39.11^{b}	1.68^{b}	1.05^{b}	2.73^{b}	0.0057^{cd}	
	0.8	33.21^{b}	0.97^{a}	0.67^{ab}	1.64^{ab}	0.0050^{bc}	
	1.6	25.82^{b}	0.48^{a}	0.50^{ab}	0.98^{a}	0.0017^{ab}	
	3.2	22.50^{b}	0.38^{a}	0.50^{ab}	0.88^{a}	0.0013^{ab}	
	6.4	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.0000^{a}	
	12.8	0.00^{a}	0.00^{a}	0.00^{a}	0.00^{a}	0.0000^{a}	

Legend: Means with different letters differ at $P < 0.05$ level of probability by LSD test; *LC_{50} value unit, per mille (95% confidence interval)

because the comparisons between them were performed at equal condition.

Similar results were reported by Fernández-Aparicio et al. (2006), Qasem (2010), Lev-Yadun (2013) according to whom allelopathic effect was species specific and depended on the applied concentrations.

The differences in the inhibitory effect of the parasite weed species on the seed germination of the *L. sativa* can be explained by diffusion of soluble allelochemicals in the available biomass of the parasitic weed species in the agar (Li et al., 2010).

This most often are total phenols, water soluble sugars and others (Höniges et al., 2009; Othman et al., 2012).

Biochemical analysis revealed that the content of to-

Table 3
Index of development and coefficients of depression on the germination and initial development of the *Lactuca sativa* L. depending on factors studied

Variants		Germination				Seedlings length			Seedling weight			GI
	Concentration, %w/v	DDI	RI.10^2	***µ.10***^{2}	GR%	DDI	RI.10^2	***µ.10***^{2}	DDI	RI.10^2	***µ.10***^{2}	
C. epithymum	0.4	-17.5	-0.6	-0.1	93.1	-2.6	-3.6	-0.9	-12.9	-0.8	-0.2	60.5
	0.8	-3.2	-2.9	-0.7	69.6	-2.0	-4.4	-1.2	-8.0	-1.3	-0.3	39.7
	1.6	-2.1	-4.2	-1.1	56.3	-1.8	-4.7	-1.3	-5.3	-1.9	-0.4	31.1
	3.2	-1.9	-4.6	-1.2	50.0	-1.7	-4.9	-1.3	-3.9	-2.5	-0.6	27.9
	6.4	-0.6	-8.7	-4.1	3.9	-0.6	-8.3	-3.5	-0.8	-7.7	-3.0	2.3
	12.8	-0.6	-8.7	-4.1	-4.9	-0.5	-8.9	-4.5	-0.9	-7.3	-2.6	1.9
C. campestris	0.4	-3.2	-0.3	-0.1	70.1	-1.5	-0.5	-0.2	-2.4	-0.4	-0.1	32.7
	0.8	-1.6	-0.5	-0.1	49.2	-1.3	-0.6	-0.2	-1.6	-0.5	-0.1	21.0
	1.6	-1.5	-0.5	-0.2	43.9	-1.0	-0.7	-0.2	-1.2	-0.6	-0.2	14.7
	3.2	-0.7	-0.8	-0.3	14.0	-0.7	-0.8	-0.3	-0.6	-0.9	-0.4	4.0
	6.4	*	*	*	*	*	*	*	*	*	*	*
	12.8	*	*	*	*	*	*	*	*	*	*	*
Ph. ramosa	0.4	-17.4	-0.1	0.0	93.2	-2.6	-0.4	-0.1	0.0	0.0	0.0	60.7
	0.8	-1.3	-0.6	-0.2	40.4	-1.4	-0.6	-0.2	-5.0	-0.2	-0.1	18.8
	1.6	-1.1	-0.6	-0.2	34.7	-0.7	-0.8	-0.3	-2.2	-0.4	-0.1	7.9
	3.2	-0.7	-0.8	-0.3	14.0	-0.7	-0.8	-0.3	-0.9	-0.7	-0.2	4.0
	6.4	*	*	*	*	*	*	*	*	*	*	*
	12.8	*	*	*	*	*	*	*	*	*	*	*
Ph. mutelii	0.4	-1.9	-0.5	-0.1	53.9	-1.6	-0.5	-0.1	-5.0	-0.2	-0.1	27.1
	0.8	-1.5	-0.5	-0.2	45.0	-1.0	-0.7	-0.2	-3.9	-0.3	-0.1	14.9
	1.6	-0.8	-0.8	-0.3	20.9	-0.7	-0.8	-0.3	-0.7	-0.8	-0.3	4.6
	3.2	*	*	*	*	*	*	*	*	*	*	*
	6.4	*	*	*	*	*	*	*	*	*	*	*
	12.8	*	*	*	*	*	*	*	*	*	*	*
Phelipanche spp.	0.4	-1.8	-0.5	-0.1	53.8	-2.1	-0.4	-0.1	-2.9	-0.3	-0.1	31.9
	0.8	-1.5	-0.5	-0.2	45.0	-1.1	-0.7	-0.2	-2.2	-0.4	-0.1	16.3
	1.6	-1.1	-0.6	-0.2	33.6	-0.7	-0.8	-0.3	-0.7	-0.8	-0.3	7.6
	3.2	-1.0	-0.7	-0.2	26.8	-0.7	-0.8	-0.3	-0.6	-0.9	-0.4	5.9
	6.4	*	*	*	*	*	*	*	*	*	*	*
	12.8	*	*	*	*	*	*	*	*	*	*	*

Legend: * – Inhibit the germination of Lactuca sativa L. of 100% is not calculated

tal phenols and water soluble sugars in the biomass of the parasitic weed species varies depending on the weed species (Table 4).

The results obtained confirm notified by Ashrafi et al. (2007) and Bhadoria (2011) according to them during weed biomass extraction allelochemicals are extracted that are not possibly released during extraction under natural conditions in agrophytocenoses.

The data of the biometric measurements of the length of the seedlings growth (cm) gave possibility for objective estimation of the differences at the initial developmental stages of

Table 4
Biochemical characterization of parasitic weeds

Species	% DM					%	
	N	P	Ca	CF	TMC	TF	WSS
C. epithymum	2.13	0.56	11.03	16.46	11.70	0.96	5.00
C. campestris	2.17	0.67	0.98	16.76	10.71	1.0	5.50
Ph. ramosa	1.53	0.38	1.47	9.88	27.96	0.70	2.40
Ph. mutelii	1.61	0.39	0.66	15.16	11.44	1.79	2.50
Phelipanche spp.	1.60	0.37	0.452	10.04	25.74	1.52	3.70

Legend: N – nitrogen; P – phosphorus; Ca *– calcium; CF – crude fiber; TMC -total mineral content (ash); TF – total phenolics; WSS – Water soluble sugars*

the *L. sativa* depending on the type and concentration of the applied weed biomass from parasitic weed species (Table 2).

All study parameters (root stem and seedling) on *L. sativa* significantly influenced (P<0.05) of allelopathic interactions on the parasitic plant species (Table 2).

The available parasitic weeds had a depressive effect on the growth of (root stem and seedling) on *L. sativa*. With increase of the concentration (from 0.4 to 12.8% w/v), all study parameters growth decreased disproportionately in all test plants, as compared to the control treatment, the differences being statistically significantly smaller at P<0.05.

The inhibition rate on the root, stem and seedling on *L. sativa* growth increased disproportionately with increase of weed biomass content, on average from 4.32 to 12.45 times for species of *Cuscuta* and from 4.32 to 6.55 times for species of *Orobanhe* (Table 3).

The obtained experimental data confirmed the results of Ashrafi et al. (2007) and Othman (2012), according to which the effect of the allelochemicals is manifested already during the seed germination, but it is more pronounced during the growth of primary seedlings of plants.

The mathematical and statistical analysis of the obtained results showed that all tested parasite plants weeds had a strong inhibitory effect on the initial development of the test plants, the differences were statistically significant at P<0.05.

Index phytotoxic effect (*RI*) and the rate of accumulation of fresh biomass of seedlings from *L. sativa* (μ) depends on the type and concentration of the applied biomass from parasitic weed species (Table 3). The relatively slight phytotoxic effect was observed in the lowest concentration of 0.4% w/v and increasing to 12.8 % w/v *RI* and μ decreased from 2.0 to 13.0 times, but the *DDI* increased from 0.07 to 0.25 times.

There is a general trend to reduce the fresh biomass for all studied variants depending on the type and concentration of of the applied biomass from parasitic weed species. Exception to the described dependence is observed at the lowest applied concentrations (0.4 – 0.8% w/v) in treatments *C. epithymum, Ph. ramosa, Ph. mutelii* and *Phelipanche* spp., where the differences are not statistically proven P<0.05.

The index germinations (*GI*) depended on the same factors and followed the observed relationship pattern with regard to laboratory seed germination and growth of seedling of test plants – *L. sativa* (Table 3). The analyses indicated that the studied parasitic weed species showed a high allelopathic activity – *GI* varied on average from 1.9 to 60.7% depending on the applied concentrations and can be arranged in the following order: *C. epithymum* → *Ph. ramosa* → *C. campestris* → *Ph. mutelii* → *Phelipanche* spp.

There was a specific reaction with regard to the allelopathic effect of the tested parasitic weed species weeds on seedling growth of *L. sativa* (Table 5).

On the basis of screening can be concluded that the parasitic weed species from family *Orobanchaceae* [*Ph. ramosa*, *Ph. mutelii* and *Phelipanche* spp.] showed a considerably stronger allelopathic effect ($GI_{average}$ 17.9), as compared with the applied concentrations from water exracts of the parasitic weed species of family *Convolvulaceae* [*C. epithymum* and *C. campestris*] ($GI_{average}$ 22.7).

Conclusion

The applied concentration from 0.4 to 12.8% w/v of parasitic weed species of Dodder [*C. epitium* (CVCEY) and *C. campestris* (CVCCA)] and Broomrape [*Ph. ramosa* (ORARA)*, Ph. mutelii* (ORARM) and *Phelipanche* spp. (PHESS)] showed a relative high inhibitory effect on the seed germination of test plants – *L. sativa*. The inhibiting rate for family *Convolvulaceae* (COVF) ranges from 6.24 to 100.0% and for the species of family *Orobanchaceae* (ORAF) is considerably higher and ranges from 42.1 to 100.0%. The LC_{50} values ranges from 1.00 to 2.23% w/v according to applied dry biomas for the species from family

Table 5

Assessment allelopathic activity of some parasitic plants on germination and initial development of *Lactuca sativa* L. under laboratory conditions

Plant taxonomy		Germination, %	Root, cm	Stem, cm	Seedling, cm	Seedling fresh weight, g
Family	Convolvulaceae	29.32^{a}	0.90^{a}	1.20^{b}	2.10^{b}	0.0038^{a}
	Orobanchaceae	19.27^{a}	0.84^{a}	0.75^{a}	1.59^{a}	0.0028^{a}
Species	*C. epithymum*	36.36^{b}	0.99^{bc}	1.42^{c}	2.41^{c}	0.0038^{a}
	C. campestris	22.27^{ab}	0.74^{ab}	0.84^{ab}	1.58^{ab}	0.0028^{a}
	Ph. ramosa	22.88^{ab}	1.07^{c}	0.96^{b}	2.03^{b}	0.0038^{a}
	Ph. mutelii	14.84^{a}	0.55^{a}	0.62^{a}	1.17^{a}	0.0024^{a}
	Phelipanche spp.	20.11^{ab}	0.87^{abc}	0.63^{a}	1.50^{a}	0.0025^{a}

Legend: Means with different letters differ at P < 0.05 level of probability by LSD test

Convolvulaceae are from 0.57 to 1.03% w/v of dry biomas from family *Orobanchaceae*. Depending on the inhibitory effect of water exracts of the parasitic weed species on germination of seeds of *L. sativa*, can be arranged in the following order: *C. epithymum* [2.23% w/v (1.91 – 2.60% w/v)] → *Ph. ramosa* [1.03% w/v (0.91 – 1.17% w/v)] → *C. campestris* [1.00% w/v (0.79 – 1.27% w/v)] → *Ph. mutelii* [0.57% w/v (0.31 – 1.02% w/v)] → *Phelipanche* spp. [0.57% w/v (0.31 – 1.02% w/v)]. The studied parasitic weed species showed a high allelopathic activity, species from family *Orobanchaceae* [*Ph. ramosa*, *Ph. mutelii* and *Phelipanche* spp.] showed a considerably stronger allelopathic effect ($GI_{average}$ 17.9), as compared with the applied concentrations of water exracts of species from family *Convolvulaceae* [*C. epithymum* and *C. campestris*] ($GI_{average}$ 22.7).

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