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Comparative characteristics of *Lupinus albus* L. and *Lupinus luteus* L. under allelopathic effect of *Sorghum halepense* L. (Pers.)

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SUMMARY

Allelopathic effects of aqueous extracts of *Sorghum halepense* L. (Pers.) on seed germination and primary seedling growth and development of two lupine species was studied. *Lupinus albus* and *Lupinus luteus* showed different levels of susceptibility to the allelopathic effect of weed extracts. Increasing concentrations (1.25, 2.50, 5.00 and 10.00%) of extracts from aboveground and belowground biomass suppressed seed germination of *L. luteus* from 53.2 to 74.7%. The germination of *L. albus* seeds was unaffected, except by the highest concentration of 10.00%. Fresh biomass accumulation in the initial germ of *L. luteus* was inhibited by 3.8-40.3% under the effect of concentrations of 2.50, 5.00 and 10.00%, which made the species susceptible to *S. halepense* extracts. *L. albus* was tolerant as it was not found to sustain a significant allelopathic effect of the extracts.

Keywords: *Sorghum halepense*; Lupines; Allelopathy

INTRODUCTION

Successful use of lupines (*Lupinus* species; Fabaceae) in modern agriculture is based on their high seed protein content, their forage value, ability to grow in infertile soils, contribution to soil N, and role in crop rotation with non-legumes (Lambers et al., 2013). Today the genus *Lupinus* comprises approximately 270 species (Gladstones, 1998; Wolko et al., 2011). *Lupinus albus* L. and *Lupinus luteus* L. belong to a group of economically important species (Kostov & Pavlov, 1999; Lambers et al., 2013).

Yield decrease of many crops is largely due to allelopathy (Hobbs et al., 2006). Allelopathy is an influence that plants exert one upon another through release of chemical substances. Allelochemicals are synthesized in all plant tissues, including leaves, stems, roots, rhizomes, flowers, seeds and pollen and they can be released into the environment by evaporation, leaching, root exudation and decomposition of plant residues (Putham & Tang, 1986). Allelopathy plays an important role in agroecosystems and leads to a wide array of interactions between crops and weeds (Singh et al., 2003). It may affect seed germination,

root development and absorption of nutrients. In most cases, the influence is inhibitory, which explains why some plants do not grow in the presence of particular other plants (Sexton et al., 2002; Butnariu & Bostan, 2011; Golubinova & Ilieva, 2014). In order to determine an allelopathic relationship between certain weeds and crop plants, Moosavi et al. (2011) and Nouri et al. (2012) used plant extracts from dry weed biomass because such extracts had significantly higher concentrations than plants growing in agrophytocenoses. According to some authors (Alam & Islam, 2002; Tinnin & Muller, 1972) different parts of weed plants have different allelopathic potentials.

Sorghums (*Sorghum* sp.) are crop species with considerable allelopathic potential (Dayan, 2006; Sikora & Berenji, 2008; Butnariu et al., 2012). Using up-to-date laboratory techniques, Sikora and Berenji (2008) isolated various allelochemicals from sorghum stems, leaves and roots. The most important allelochemicals are phenolic acids and a long-chain hydroquinine called sorgoleone. Allelochemicals have either inhibitory or stimulative effects on acceptor plants, and their intensity depends on concentration (Sikora & Berenji, 2008).

Sorghum halepense L. (Pers.), a herbaceous plant of the genus *Sorghum*, is one of the most harmful weeds for agricultural crops, especially in dry regions (Mihovsky & Pachev, 2012). Based on its nearly worldwide distribution and adverse effect on global economy it is often described as one of the world's 10 worst weeds (Holm et al., 1977; Howard, 2004). *S. halepense* infestation results in severe crop losses either from competition or allelopathic effects and/or by serving as an alternative host for several crop pests (Warwick & Black, 1983). Its root system typically extends to a depth exceeding 1 m. The species grows up to three meters in height (Yang et al., 2004; Uddin et al., 2010). Chemical analyses of aqueous extracts of *S. halepense* have indicated the presence of sorgoleone and dihydrosorgoleone (Stef et al., 2013). These compounds have toxic effects manifested as inhibition of seedling growth, decrease in photosynthetic pigment content and blockage of respiration and photosynthesis in other plants (Butnariu et al., 2005; Dayan et al., 2010; Stef et al., 2013).

Some studies in the past several years have indicated the existance of varieties and genotypes of crops which are low-sensitive or tolerant to some extent to the allelopathic impact of other crop and weed species (Aleksieva & Marinov-Serafimov, 2008; Golubinova & Georgieva, 2009). Similar results have also been reported by Rice (1995) and Wu et al. (1998), showing that cultivated species and varieties have different levels of susceptibility to the allelopathic effect of plant extracts and that allelopathic effect is species-specific and depends on concentration (Einhelling, 1996; Marinov-Serafimov, 2010). These species and varieties could be used in organic production or as components of breeding programmes in the future.

The objective of this study was to compare tolerance levels of *L. albus* and *L. luteus* to aqueous extracts of *S. halepense* based on their seed germination and initial growth of test plants in the laboratory.

MATERIAL AND METHODS

The study was conducted in a laboratory of the Institute of Forage Crops in Pleven, Bulgaria, in 2014.

Collection and preparation of plant material. There are no registered varieties of lupines in the Official Variety Catalog of Bulgaria. Seeds of two introduced lupine varieties, namely Garant and Chernilovets, representing *L. albus* and *L. luteus*, respectively, were used in the experiment. The seeds of the studied species (varieties) were harvested in 2013. Control seeds belonged to another legume crop, namely the pea (*Pisum sativum* L.) variety Pleven 4, which is notable for its high susceptibility to allelopathic impact of different weeds (*Solanum nigrum* L.*, Chenopodium album* L.*, Amaranthus retroflexus* L.*, Erigeron canadensis* L.*, S. halepense*) (Marinov-Serafimov & Dimitrova, 2007; Marinov-Serafimov, 2010; Kalinova et al., 2012).

Above-ground and below-ground biomass of *S. halepense* was sampled at the flowering stage. Plant material was dried to constant dry weight of 55 ± 3^0C (Chon & Nelson, 2001).

Preparation of weed extracts. A hundred grams of above-ground and belowground biomass of *S. halepense* were cold extracted in 1 l of distilled water at a temperature of 24 ± 2^0C for 24 h in a shuttle apparatus at 240/60s^{-1}. The extracts were decanted, filtered through filter paper and centrifuged in a "K24" centrifuge at 5000/60 s^{-1}. All available aqueous extracts were brought to final concentrations of 12.5, 25.0, 50.0 and 100 g dry biomass per liter of distilled water (g l^{-1}), or respectively: 1.25, 2.5, 5.0 and 10.0%. Thymol ($C_{10}H_{14}O$, 1 g l^{-1}) was added to each extract as a preserving agent (Marinov-Serafimov et al*.,* 2007).

Bioassay techniques. To assess the effects of cold aqueous extracts of *S. halepense* on seed germination and initial growth of test plants*,* 20 seeds of each species

(*L. albus*, *L. luteus* and *P. sativum*) were placed in Petri dishes (9 cm in diameter) on filter paper. The extracts were pipetted at a ratio to seed weight of 1:6 in Petri dishes (Marinov-Serafimov et al., 2007). Distilled water was used as a control. Each variant had four replications. The prepared samples were placed in a thermostat at a temperature of 22°C ± 2^0 C (Moyer & Huang, 1997) for seven days (Adetayo et al., 2005; Liebman & Sundberg, 2006).

The following parameters were determined: initial seedling length (root + stem) (cm), weight of root, stem and germ (g). Germination index (GI) was calculated as described by the Association of Official Seed Analysts (AOSA, 1983) using the following formula: GI = number of germinated seed / days of count. Inhibition effect (%) (IR) of the extracts on germination was calculated following a formula forwarded by Feng-Min & Hong-Ying (2005):

IR = $[1 - (N/N_0)] \times 100$, where:

N_0 – number of germinated seeds in the control variant;

N – number of germinated seeds in the studied variant.

Speed of growth ($K_{cm/t}$) and speed of biomass accumulation ($K_{g/t}$) in the root, stem or germ were determined for all variants depending on the studied factors using a formula of Mamonov and Kim (1978):

$$K = \frac{(W_2 - W_1)}{(t)};$$

where: W_1 – control variant; W_2 – studied variant; t – duration (7 days).

Statistical analysis. The percentage of seed germination was calculated after preliminary transformation following the formula, $Y = arcsin\ \sqrt{(x_{\%} / 100)}$, forwarded by Hinnkelman & Kempthorne (1994), and statistically processed by the φ-criteria of Ficher (cited by Plohinskij, 1967). The results were processed in the STATGRAPHICS Plus package for Windows Version 2.1 at LSD 0.05%.

RESULTS AND DISCUSSION

The studied species (varieties) of lupines demonstrated different levels of susceptibility to the allelopathic effect of *S. halepense* extracts. Data in Table 1 show that the influence of aqueous extracts on seed germination of *L. luteus* was significant (P≥0.001). With increasing concentrations of all tested extracts of aboveground and belowground weed biomass a general tendency was observed of decreasing laboratory germination (by 53.2-74.7%), compared to the control. However, germination of *L. albus* was mostly unaffected by the tested extracts of *S. halepense,* while a significant inhibitory effect was only found for the highest concentration (10%) of aboveground and belowground biomass. Similar results of lacking inhibitory effect on seed germination in *Lupinus perennis L.* under the influence of *S. halepense* extracts had been reported by Stef et al. (2013). The authors suggested that seeds used their own reserves for the germination process and were not yet inhibited by the extracts at that early stage of development. The average values of seed germination of *P. sativum* in our present study were between those of *L. luteus* and *L. albus*. Increasing concentrations of the aboveground and belowground biomass extracts resulted in decreasing germination of peas with close average values of 80.0 and 80.3% respectively, compared to the control.

Regarding the inhibition effect (%, IR) of the extracts on germination, the studied species showed considerable differences. The highest percentage of inhibition was found in *L. luteus* (38.7%), then in *P. sativum* (19.9%) and *L. albus* (3.6%). Weed extract from aboveground biomass had a greater inhibitory effect on *L. luteus* and *P. sativum* than belowground biomass. There was not a similar trend in *L. albus* because the aboveground and belowground biomass extracts had the same effect on that species.

Biometric measurements of primary seedling length and germ weight allowed an objective assessment of potential allelopathic effects of the tested extracts on initial development stages of the studied species. Different concentrations of *S. halepense* extracts in their greater part had inhibitory effect on the primary growth of root, stem and germ of all three species (Table 2). Exceptions were found for the 2.5% concentration of aboveground biomass and 5.0% of belowground biomass, which had low and insignificant stimulative effect on root development of *L. albus.* In pea, this stimulation was evident at the lowest 1.25% concentration of aboveground and belowground biomass of *S. halepense*. Generally, inhibitory effects of the tested extracts on germ length of the three legumes were higher and statistically significant at higher concentrations. It should be noticed that suppressive effects of all concentrations of aboveground and belowground *S. halepense* extracts were more evident in *L. luteus,* whose germ length reduction was 41.8 and 28.9%, respectively, compared with 15.6 and 17.0% in *L. albus*.

Table 1. Effects of *Sorghum halepense* aqueous extracts on seed germination of studied species and percentage of inhibition

Species	Type of *S. halepense* extract	Concentration %	Seed germination %	Inhibition rate	Fϕ	P
Pisum sativum	Aboveground biomass	0	100.0	0	0.00	
		1.25	85.6	14.4	0.00	ns
		2.5	85.6	14.4	2.44	*
		5.0	85.6	14.4	2.44	*
		10.0	63.1	36.9	5.41	***
	Roots (rhizomes)	0	100.0	0	0.00	
		1.25	100.0	0	0.00	ns
		2.5	85.6	14.4	2.44	*
		5.0	85.6	14.4	2.44	*
		10.0	50.0	50	7.73	***
Lupinus albus	Aboveground biomass	0	100.0	0	0.00	
		12.5	100.0	0	0.00	ns
		2.5	100.0	0	0.00	ns
		5.0	100.0	0	0.00	ns
		10.0	85.6	14.4	2.44	*
	Roots (rhizomes)	0	100.0	0	0.00	
		12.5	100.0	0	0.00	ns
		2.5	100.0	0	0.00	ns
		5.0	100.0	0	0.00	ns
		10.0	85.6	14.4	2.44	*
Lupinus Luteus	Aboveground biomass	0	100.0	0	0.00	
		12.5	70.5	29.5	4.17	***
		2.5	59.7	40.3	5.98	***
		5.0	53.2	46.8	7.10	***
		10.0	53.2	46.8	7.10	***
	Roots (rhizomes)	0	100.0	0	0.00	
		12.5	74.7	25.3	3.51	***
		2.5	59.7	40.3	5.98	***
		5.0	56.4	43.6	6.58	***
		10.0	63.1	36.9	5.41	***
$t_{krit.\ at\ 0.05\ probability\ level}$			2.024			
$t_{krit.\ at\ 0.01\ probability\ level}$			2.711			
$t_{krit.\ at\ 0.001\ probability\ level}$			3.565			

Statistical processing to prove differences in seed germination was performed using Fischer's test „Fϕ" modified by the „ϕ" method at t krit (P≥0.05)*; t krit (P≥0.01)**; t krit (P≥0.001)*** and ns – non-significant

Table 2. Effects of *Sorghum halepense* aqueous extracts on initial length and fresh biomass accumulation in germs of the studied species

Species	Type of *S.halepense* extract	Concentration %	Indicators					
			Root length cm	Stem length cm	Germ length cm	Root weight g	Stem weight g	Germ weight g
Pisum sativum	Aboveground biomass	0	7.53	6.11	13.64	0.13	0.15	0.28
		12.5	7.97	6.16	14.13	0.13	0.17	0.30
		2.5	6.45	5.59	12.04	0.11	0.15	0.26
		5.0	4.19	5.08	9.27	0.08	0.09	0.17
		10.0	2.92	3.31	6.23	0.06	0.09	0.15
	Roots (rhizomes)	0	7.53	6.11	13.64	0.13	0.15	0.28
		12.5	8.83	6.31	15.14	0.10	0.14	0.23
		2.5	2.07	3.65	5.72	0.07	0.11	0.17
		5.0	1.93	3.14	5.07	0.05	0.10	0.15
		10.0	0.43	0.64	1.07	0.02	0.02	0.04
Lupinus albus	Aboveground biomass	0	7.65	4.60	12.24	0.22	0.98	1.20
		12.5	7.42	3.46	10.88	0.14	1.01	1.16
		2.5	8.07	3.58	11.64	0.18	1.15	1.33
		5.0	7.34	2.85	10.19	0.16	1.05	1.21
		10.0	5.86	2.76	8.62	0.14	0.99	1.13
	Roots (rhizomes)	0	7.65	4.60	12.24	0.22	0.98	1.20
		12.5	6.41	2.99	9.41	0.16	1.11	1.27
		2.5	6.63	2.44	9.06	0.16	1.16	1.32
		5.0	8.04	3.76	11.79	0.16	1.11	1.28
		10.0	7.32	3.04	10.36	0.14	0.99	1.13
Lupinus luteus	Aboveground biomass	0	3.55	3.16	6.70	0.10	0.42	0.52
		12.5	2.68	2.51	5.19	0.10	0.35	0.45
		2.5	1.36	1.50	2.86	0.05	0.25	0.31
		5.0	1.08	1.75	2.82	0.06	0.25	0.31
		10.0	2.42	2.31	4.73	0.07	0.34	0.41
	Roots (rhizomes)	0	3.55	3.16	6.70	0.10	0.42	0.52
		12.5	2.96	2.88	5.84	0.09	0.40	0.50
		2.5	1.54	1.87	3.41	0.06	0.27	0.33
		5.0	2.43	2.33	4.76	0.08	0.22	0.30
		10.0	2.49	2.55	5.04	0.07	0.29	0.36
LSD at the 0.05 probability level			cm	cm	cm	g	g	g
Factor A			0.628	0.566	0.566	0.566	0.566	0.566
Factor B			0.512	0.653	1.081	0.019	0.056	0.070
Factor C			0.810	1.033	1.709	0.029	0.089	0.101
Factor AxB			0.887	1.132	1.872	0.032	0.097	0.121
Factor AxC			1.403	1.789	2.960	0.051	0.153	0.191
Factor BxC			1.146	1.461	2.417	0.041	0.125	0.156
Factor AxBxC			1.984	1.984	4.187	0.072	0.217	0.270

The tested species (i.e. varieties) showed different levels of susceptibility to the allelopathic effect of *S. halepense* extracts with regard to initial germ biomass accumulation (Table 2). In *L. luteus,* inhibitory effects of the weed extracts were detected on root biomass (average 28.8%) and stem biomass (17.8%). A significant suppressive effect on *L. albus* was observed only regarding its root development (31.8% on average), while stem development was stimulated by all concentrations (9.3% on average). As a summary indicator, the germ weight (root + stem) of *L. luteus* was reduced significantly, from 3.8 to 40.3%, by concentrations of 2.5, 5.0 and 10.0%, which defined the species as susceptible to cold aqueous extracts of *S. halepense. L. albus* demonstrated some tolerance to the allelopathic effect as no statistically significant differences were found in the studied parameters between the applied extracts and the control variant. Lower concentrations (1.25, 2.5 and 5.0%) insignificantly stimulated germ development in this species (7.5%). Looking at the response of *P. sativum* to *S. halepense* extracts as a comparative characteristic for lupine species, the pea could be considered as the most susceptible of these three species – increasing extract concentrations caused the degree of inhibition of fresh biomass accumulation to increase 7.1-85.7%, compared to the control, the differences being statistically significant for the two highest concentrations (5.0 and 10.0%). Different reactions of *L. albus* and *L. luteus* to the extracts were probably determined by different chemical composition of their seeds and their physicochemical properties (seed weight, bulk density, volume, water absorption, seed coat content, etc.). A similar study had been performed on *L. albus* (Tizazu & Emire, 2010) but there was no data and comparison with *L. luteus*.

Data from our dispersion analysis showing hierarchical allocation of variations among factors determing the allelopathic effect of concentrations on the tested species showed that factors A and C had statistically significant action but factor A (species) had the strongest effect (Table 3a). Regarding weight parameters, factor A had a statistical significance, while differences between factor C and the other factors had statistical significance only regarding root weight (Table 3b).

Table 3a. Main effects of the factors tested

Causes of variation	Degrees of freedom	Sum of squares	Mean square	Influence of factors	Sum of squares	Mean square	Influence of factors	Sum of squares	Mean square	Influence of factors
Indicators		Root length			Stem length			Germ length		
Total	119.00	1021.63		100.00	547.54		100.00	2549.26		100.00
Factor A - species	2	467.64	233.82^{+}	45.8	97.99	48.99^{+}	17.9	775.01	387.51^{+}	30.4
Factor B - type of extract	1	5.94	5.94^{ns}	0.6	3.70	3.70^{ns}	0.7	19.02	19.02^{ns}	0.7
Factor C - concentration of extracts	4	136.94	34.23^{+}	13.4	71.32	17.83^{+}	13.0	401.20	100.30^{+}	15.7
Interaction										
AxB	2	22.97	11.49^{+}	2.2	13.72	6.86^{ns}	2.5	72.18	36.09^{+}	2.8
AxC	8	159.59	19.95^{+}	15.6	50.77	6.35^{ns}	9.3	365.21	45.65^{+}	14.3
BxC	4	15.96	3.99^{ns}	1.6	4.45	1.11^{ns}	0.8	34.36	8.59^{ns}	1.3
AxBxC	8	33.06	4.13^{+}	3.2	13.65	1.71^{ns}	2.5	83.18	10.40^{ns}	3.3
Error	90	179.53	1.99	17.6	291.93	3.24	53.3	799.09	8.88	31.3

LSD at 0.05 probability level

Table 3b. Main effects of the factors tested

Causes of variation	Degrees of freedom	Sum of squares	Mean square	Influence of factors	Sum of squares	Mean square	Influence of factors	Sum of squares	Mean square	Influence of factors
Indicators		Root weight			Stem weight			Germ weight		
Total	119.00	0.5280		100.00	27.7309		100.00	26.9913		100.00
Factor A - species	2	0.1941^{+}	0.0970	36.8	19.1743^{+}	9.5867	69.1	23.0018	11.5009^{+}	85.2
Factor B - type of extract	1	0.0027^{ns}	0.0027	0.5	0.0087^{ns}	0.0087	0.0	0.0018	0.0018^{ns}	0.0
Factor C - concentration of extracts	4	0.0618^{+}	0.0155	11.7	0.0587^{ns}	0.0147	0.2	0.2088	0.0522^{ns}	0.8
Interaction										
AxB	2	0.0064^{ns}	0.0032	1.2	0.0291^{ns}	0.0146	0.1	0.0628	0.0314^{ns}	0.2
AxC	8	0.0233^{ns}	0.0029	4.4	0.2740^{ns}	0.0342	1.0	0.3391	0.0424^{ns}	1.3
BxC	4	0.0015^{ns}	0.0004	0.3	0.0277^{ns}	0.0069	0.1	0.0359	0.0090^{ns}	0.1
AxBxC	8	0.0031^{ns}	0.0004	0.6	0.0140^{ns}	0.0018	0.1	0.0279	0.0035^{ns}	0.1
Error	90	0.2351	0.0026	44.5	2.1452	0.0239	7.7	3.3133	0.0368	12.3

LSD at the 0.05 probability level

The speed of growth and speed of biomass accumulation in root, stem and germ are presented in Table 4. *L. albus* had considerably higher values of these parameters than *L. luteus* in the control. Regarding both the speed of germ growth and germ biomass accumulation, *L. albus* had 1.8- and 2.3-fold higher values. The applied concentrations of *S. halepense* extracts resulted in slowing the speed of germ growth of *L. albus* and *L. luteus* (by average -0.29 and -0.34 cm/t, respectively, for four concentrations) and the speed of germ biomass accumulation of *L. luteus* (by -0.018 g/t). Most applied concentrations increased the speed of germ biomass accumulation in *L. albus,* while a slower rate was found only for the concentration of 10.0% of belowground and aboveground biomass and 1.25% of aboveground biomass of *S. halepense*.

Resembling previous parameters, the growth index decreased with increasing weed concentrations. The extracts of aboveground biomass had a more suppressive action on *L. luteus* than those from belowground biomass. The difference in inhibitory effects of the two types of extracts was inconsiderable in *L. albus*. The average growth index for concentrations increasing from 1.25 to 10.0% was 40.4 in *L. luteus,* and it was 2-fold lower than in *L. albus*. Regarding this parameter, *P. sativum* took an intermediate position with a value of 54.2.

Table 4. Speed of growth and speed of biomass accumulation in germs of the studied species under the influence of aqueous extracts of *Sorghum halepense*

Species	Type of *Sorghum halepense* extract	Concentration, %	Indicators						
			Speed of root growth t/cm	Speed of stem growth t/cm	Speed of germ growth t/cm	Speed of root biomass accumulation t/g	Speed of stem biomass accumulation t/g	Speed of germ biomass accumulation t/g	Growth Index
Pisum sativum	Above ground biomass	0	1.08	0.87	1.95	0.040	0.021	0.040	100.0
		12.5	0.06	0.01	0.07	0.003	0.003	0.003	88.7
		2.5	–0.15	–0.07	–0.23	–0.003	0.000	–0.003	75.6
		5.0	–0.48	–0.15	–0.62	–0.016	–0.009	–0.016	58.2
		10.0	–0.66	–0.40	–1.06	–0.019	–0.009	–0.019	28.8
	Roots (rhizomes)	0	1.08	0.87	1.95	0.019	0.021	0.040	100.0
		12.5	0.19	0.03	0.21	–0.004	–0.001	–0.007	111.0
		2.5	–0.78	–0.35	–1.13	–0.009	–0.006	–0.016	35.9
		5.0	–0.80	–0.42	–1.22	–0.011	–0.007	–0.019	31.8
		10.0	–1.01	–0.78	–1.80	–0.016	–0.019	–0.034	3.9
Lupinus albus	Above ground biomass	0	1.09	0.66	1.75	0.031	0.140	0.171	100.0
		12.5	–0.03	–0.16	–0.19	–0.011	0.004	–0.006	88.9
		2.5	0.06	–0.15	–0.09	–0.006	0.024	0.019	95.1
		5.0	–0.04	–0.25	–0.29	–0.009	0.010	0.001	83.3
		10.0	–0.26	–0.26	–0.52	–0.011	0.001	–0.010	60.3
	Roots (rhizomes)	0	1.09	0.66	1.75	0.031	0.140	0.171	100.0
		12.5	–0.18	–0.23	–0.40	–0.009	0.019	0.010	76.9
		2.5	–0.15	–0.31	–0.45	–0.009	0.026	0.017	74.0
		5.0	0.06	–0.12	–0.06	–0.009	0.019	0.011	96.3
		10.0	–0.05	–0.22	–0.27	–0.011	0.001	–0.010	72.5
Lupinus luteus	Above ground biomass	0	0.51	0.45	0.96	0.014	0.060	0.074	100.0
		12.5	–0.12	–0.09	–0.22	0.000	–0.010	–0.010	54.6
		2.5	–0.31	–0.24	–0.55	–0.007	–0.024	–0.030	25.5
		5.0	–0.35	–0.20	–0.55	–0.006	–0.024	–0.030	22.4
		10.0	–0.16	–0.12	–0.28	–0.004	–0.011	–0.016	37.5
	Roots (rhizomes)	0	0.51	0.45	0.96	0.014	0.060	0.074	100.0
		12.5	–0.08	–0.04	–0.12	–0.001	–0.003	–0.003	65.1
		2.5	–0.29	–0.18	–0.47	–0.006	–0.021	–0.027	30.4
		5.0	–0.16	–0.12	–0.28	–0.003	–0.030	–0.030	40.1
		10.0	–0.15	–0.09	–0.24	–0.004	–0.020	–0.020	47.5

CONCLUSIONS

L. albus and *L. luteus* showed different levels of susceptibility to the allelopathic effect of aqueous extracts from belowground and aboveground biomass of *S. halepense*.

Increasing concentrations (1.25, 2.5, 5.0 and 10.0%) of the aboveground and belowground biomass extracts suppressed seed germination of *L. luteus* from 53.2 to 74.7%. The germination of *L. albus* seeds was not influenced by the tested aqueous extracts, except by the highest concentration of 10.0%.

The inhibitory effect of *S. halepense* on germ development in the tested plants mainly increased with increasing extract concentrations. It was more pronounced in *L. luteus,* where the reduction in germ length was 41.8 and 28.9% (for aboveground and belowground biomass extracts, respectively), while the corresponding values for *L. albus* were 15.6 and 17.0%.

The extract from aboveground biomass had a stronger inhibitory effect on *L. luteus* than belowground biomass extract. In *L. albus,* the difference between the inhibitory actions of the two types of extracts was insignificant.

Fresh biomass accumulation in the initial germ of *L. luteus* was inhibited from 3.8 to 40.3% by 2.5, 5.0 and 10.0% concentrations, which determined the species as susceptible to *S. halepense* extract. *L. albus* was tolerant as the extracts had no significant allelopathic effect on it.

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Komparativne karakteristike *Lupinus albus* L. i *Lupinus luteus* L. pod alelopatskim delovanjem *Sorghum halepense* L. (Pers.)

REZIME

Proučavan je alelopatski uticaj vodenih rastvora *Sorghum halepense* L. (Pers.) na klijanje semena i primarni rast i razvoj dve vrste lupina. Vrste *Lupinus albus* i *Lupinus luteus* su pokazale različitu osetljivost na alelopatski uticaj rastvora ispitivanog korova. Rastuće koncentracije (1.25, 2.50, 5.00 i 10.00%) ekstrakata nadzemne i podzemne biomase korova inhibirale su klijanje semena *L. luteus* od 53.2 do 74.7%. Nije bilo uticaja na klijanje semena *L. albus*, osim kod najviše koncentracije od 10.00%. Akumulacija biomase klice *L. luteus* inhibirana je 3.8-40.3% pod uticajem koncentracija od 2.50, 5.00 i 10.00%, što ovu vrstu čini osetljivom na ekstrakt *S. halepense*. *L. albus* se pokazala kao otporna vrsta jer na nju ispitivani ekstrakti nisu pokazali značajan alelopatski uticaj.

Ključne reči: *Sorghum halepense*; lupina; alelopatija