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ALLELOPATHIC ACTIVITY OF CREEPING THISTLE WATER EXTRACTS ON GERMINATION AND EARLY GROWTH OF WINTER WHEAT

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Abstract

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Allelopathic activity of creeping thistle *Cirsium arvense* (L.) Scop. over-ground and rootstock biomass water extracts affects winter wheat *Triticum aestivum* L. grain germination and early growth. Separately grinded 75 g of creeping thistle over-ground part and rootstocks was stirred into 750 mL of distilled water and left for 24 hours at a room temperature. Filtered water extract was taken as a stock solution. Stock solution was applied in two, five and ten fold dilution. Winter wheat grain germination was suppressed increasing concentration of *Cirsium arvense* water extracts while at low concentrations it slightly stimulated grain germination. *Cirsium arvense* over-ground part was more phytotoxic to the winter wheat grain germination than its rootstock stock solution. Recipient plant concentration (number of winter wheat grains) per *Petri* dish had no significant $P > 0.05$ influence on grain germination intensity. Increase of *Cirsium arvense* water extracts concentration led to winter wheat radicle length decline while seedling growth was suppressed sustaining longer one (except stock solution) than in control treatment of distilled water. *Cirsium arvense* rootstock water extracts were more phytotoxic to winter wheat seedling and radicle early growth than its over-ground part water extracts while winter wheat radicle as well seedling length was shorter applying *Cirsium arvense* rootstock than its over-ground part water extracts. Increase in concentration of *Cirsium arvense* regularly increased winter wheat seedling and radicle ratio from 0.87-0.98 to 2.84-3.38 (over-ground water extracts) and from 0.69-0.90 to 4.48-5.94 (rootstock water extracts), describing change from relatively more intensive radicle to seedling growth.

Key words: Allelopathy, *Cirsium arvense* (L.) Scop., grain, radicle, seedling, *Triticum aestivum* L., weed

Introduction

Allelopathy is the direct or indirect effect of one plant on another through substances liberated into the environment, and occurs widely in natural plant communities. The secondary metabolites or natural products involved in allelopathy are called allelochemicals and can be produced in different parts of the plants (de Moura Pires et al., 2001). In a narrow sense allelopathy describes interactions between higher plants by release of metabolic chemicals (allelochemicals). The phenomenon is common in nature and also known from weeds and crop plants (Malkomes, 2006). Different extracts of dried plant material (Khan et al., 2010) fresh plant material (Kazinczi et al., 2004), living plant parts or decomposing residues (Tesio and Ferrero, 2010) as well essential oils (Formisano et al., 2007; Azirak and Karaman, 2008) are used for allelopathic assay. Allelopathic potential, i.e. toxicity and non toxicity of selected plant species, is assessed evaluating germination, radicle and seedling growth of recipient plants (Rezaeinodehi et al., 2006; Umer et al., 2010; Pilipavičius and Romaneckas, 2014). Allelopathic interference has been demonstrated many times using *in vitro* experiments, few studies have clearly demonstrated allelopathy in natural settings. This difficulty reflects the complexity in examining and demonstrating allelopathic interactions under field conditions (Inderjit et al., 2005). *Cirsium arvense* (Californian thistle, creeping thistle) has been widely studied because of its importance as a weed of agricultural and natural ecosystems throughout most of the temperate world (Leathwick et al., 2006). *Cirsium arvense* observed to result in low species diversity in the field (Stachon and Zimdahl, 1980; Wardle, 1987). Consequently, perennial weed plants develop better,

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are stronger and grow more biomass (Jasinskaite et al., 2009). *Cirsium* genus is well known also for its ecological properties, as it possesses allelopathic activity (Chon et al., 2003; Formisano et al., 2007).

The aim of this research was to evaluate allelopathic influence of creeping thistle *Cirsium arvense* (L.) Scop. over-ground and rootstock grounded biomass water extracts on winter wheat *Triticum aestivum* L. grain germination and early growth of its seedling and radicle.

Materials and Methods

The plants of creeping thistle *Cirsium arvense* (L.) Scop. were collected at the Kaunas district Lithuania (54°52'N, 23°49'E) Research Station of the Lithuanian University of Agriculture (Aleksandras Stulginskis University) in the summer of 2010. *Cirsium arvense* plants were air-dried, divided to over-ground part and rootstocks and stored in darkness at a room temperature until use. The experimental methodology was analogous to our previous *in vitro* experiments with *Elytrigia repens* (L.) Nevski (Pilipavičius, 2012) and *Sonchus arvensis* L. (Pilipavičius et al., 2013).

In laboratory bioassays during the autumn of 2010 the allelopathic influence of grounded *Cirsium arvense* over-ground and rootstocks biomass water extracts on winter wheat *Triticum aestivum* L. variety *ADA* grain germination and early growth was investigated. After grinding, 75 g of air-dried plant part (separately over-ground and rootstocks) was stirred into 750 mL of distilled water and left for 24 hours at a room temperature. The received water and *Cirsium arvense* mixture were filtered through filter paper. Filtered water extract was taken as a stock solution. Stock solution was applied in two, five and ten fold dilutions in order to determine their effects on the winter wheat grain germination, radicle and seedling growth. Distilled water application was taken as control treatment. With the concentrations of the extracts, compensative effect of winter wheat grain number five, ten and fifteen grains per *Petri* dish jointly were checked as concentration of recipient plant. The winter wheat grain germination and early growth of its radicle and seedling length were evaluated after eleven days of grain sprouting. Winter wheat grains were put on filter paper in sterilized *Petri* dishes of ten cm diameter and watered by ten mL of experimental dilutions. During sprouting and early growth period winter wheat grains were placed at 20°C in incubator. The germination was induced keeping humidity with experimental dilutions on filter paper. The experiment was conducted in four replications (Pilipavičius and Lazauskas, 2012).

The data were subjected to two-factorial analysis of variance ANOVA applying Fisher *LSD* test at the 0.05 level of significance on statistical package *Selekcija* (Tarakanovas, 1997).

Results and Discussion

Creeping thistle *Cirsium arvense* (L.) Scop. over-ground part water extracts at low concentrations have tendency to stimulate winter wheat *Triticum aestivum* L. grain germination while increasing experimental dilution concentration grain germination was essentially suppressed especially applying stock solution (Figure 1). Water extracts prepared from *Cirsium arvense* grounded rootstock biomass showed analogous regularity stimulating and suppressing winter wheat grain germination as in its over-ground part dilutions (Figure 2). However, *Cirsium arvense* over-ground part stock solution was more phytotoxic to the winter wheat grain germination than its rootstock stock solution. Winter wheat grain germination decreased by 2.1-1.3-1.9 and 1.2-1.3-1.2 times applying *Cirsium arvense* over-ground part and rootstock stock solutions compared them with distilled water treatment, accordingly (Figures 1 and 2). Number of winter wheat grains per *Petri* dish had no significant $P > 0.05$ influence on grain germination intensity.

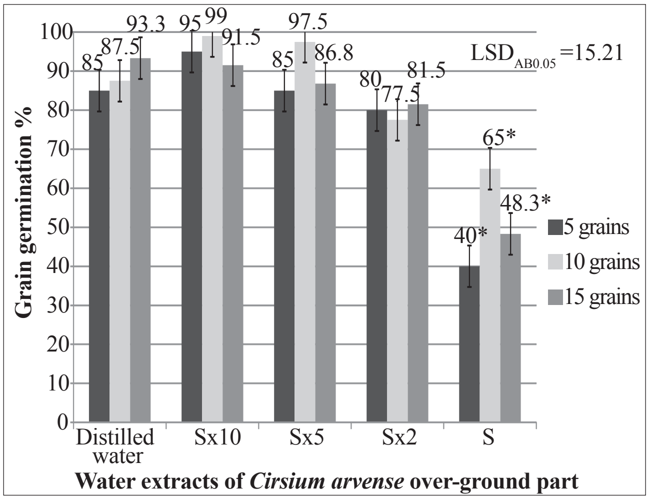

Fig. 1. The effect of *Cirsium arvense* over-ground part water extracts on winter wheat grain germination after eleven days of sprouting

Note: S – stock solution, Sx2 – two-fold dilution, Sx5 – five-fold dilution, Sx10 – ten-fold dilution, distilled water – control treatment; $LSD_{AB0.05}$ – the least significant difference at 95% level of probability; * - significant difference at 95% level of probability ($P < 0.05$) from control treatment – Petri dish with distilled water and 5 grains of winter wheat

Early growth quality of germinated winter wheat grains was evaluated measuring its seedling and radicle length. Winter wheat seedling length growth was stimulated in all *Cirsium arvense* over-ground part water extract concentrations compared them with standard distilled water treatment. Increasing *Cirsium arvense* over-ground part water extract concentration from ten fold dilution to stock solution winter wheat germinated grain seedlings growth gradually was suppressed sustaining more intensive growth than in distilled water (Figure 3). Winter wheat germinated grain radicle growth in *Cirsium arvense* rootstock water extracts either was stimulated in ten fold dilution treatment while in two fold dilution and stock solution radicle growth was essentially suppressed (Figure 4). It could be concluded that low concentrations of *Cirsium arvense* over-ground and rootstock water extract dilutions generate stressful conditions that positively stimulate winter wheat early growth of seedling and radicle. Conventionally, perennial weeds including *Cirsium arvense* in agricultural field take recessive position, i.e. they accumulate rather limited amount of biomass when applying successful agricultural technologies of weed control. Presumptively, winter wheat is well adapted to the low concentrations of *Cirsium arvense* water extract influence on its early growth while possibly similar conditions can be consisted in soil of agricultural fields.

Winter wheat seedling and radicle ratio showed regular increase from distilled water to *Cirsium arvense* over-ground part stock solution. It confirmed that winter wheat radicle growth was suppressed more intensively than its seedling growth. In control conditions (distilled water) winter wheat radicle grew longer than seedling (ratio 0.87-0.92) while in *Cirsium arvense* over-ground part stock solution media radicle were till 3.4 time shorter than seedling (Figure 5).

Cirsium arvense rootstock water extracts effect on early growth of winter wheat seedlings was similar to its over-ground part water extracts impact on winter wheat seedling growth. Low concentrations of *Cirsium arvense* rootstock water extracts of ten to two fold dilutions stimulated $P < 0.05$ winter wheat seedling growth while in stock solution seedling growth was inhibited $P < 0.05$ (Figure 6).

Applying *Cirsium arvense* rootstock water extracts was indicated tendency to increase winter wheat radicle growth in ten-fold dilution. Increase of *Cirsium arvense* rootstock water extracts concentration regularly led to winter wheat radicle growth essential suppression $P < 0.05$ (Figure 7). Winter wheat radicle as well seedling length was shorter applying

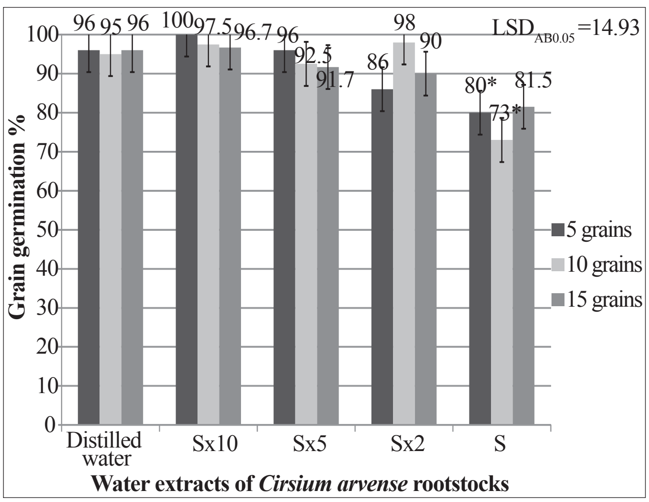

Fig. 2. The effect of Cirsium arvense rootstock water extracts on winter wheat grain germination after eleven days of sprouting

Note: S – stock solution, Sx2 – two-fold dilution, Sx5 – five-fold dilution, Sx10 – ten-fold dilution, distilled water – control treatment; $LSD_{AB0.05}$ – the least significant difference at 95% level of probability; * - significant difference at 95% level of probability ($P < 0.05$) from control treatment – Petri dish with distilled water and 5 grains of winter wheat

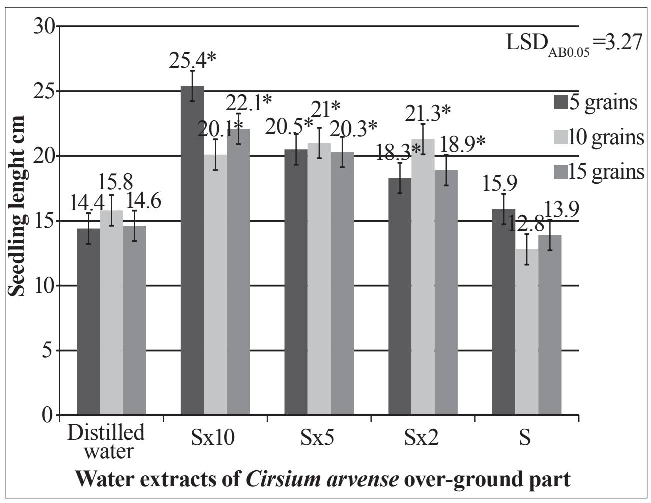

Fig. 3. The effect of *Cirsium arvense* over-ground part water extracts on early growth of winter wheat seedling length after eleven days of sprouting

Note: S – stock solution, Sx2 – two-fold dilution, Sx5 – five-fold dilution, Sx10 – ten-fold dilution, distilled water – control treatment; $LSD_{AB0.05}$ – the least significant difference at 95% level of probability; * - significant difference at 95% level of probability ($P < 0.05$) from control treatment – Petri dish with distilled water and 5 grains of winter wheat

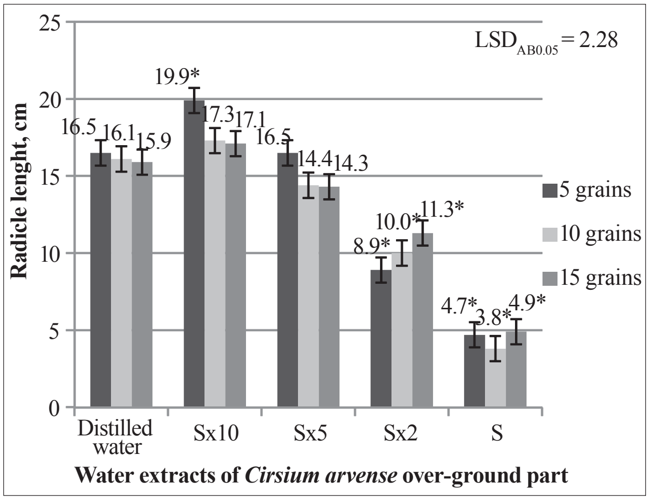

Fig. 4. The effect of *Cirsium arvense* over-ground part water extracts on early growth of winter wheat radicle length after eleven days of sprouting

Note: S – stock solution, Sx2 – two-fold dilution, Sx5 – five-fold dilution, Sx10 – ten-fold dilution, distilled water – control treatment; $LSD_{AB0.05}$ – the least significant difference at 95% level of probability; * - significant difference at 95% level of probability ($P < 0.05$) from control treatment – Petri dish with distilled water and 5 grains of winter wheat

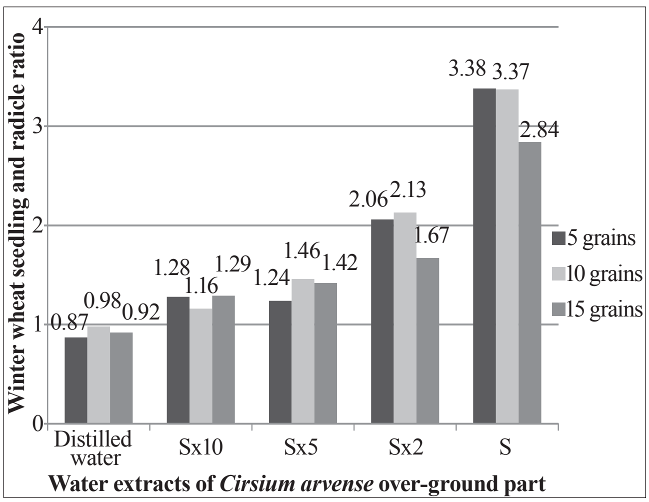

Fig. 5. The effect of *Cirsium arvense* over-ground part water extracts on early growth of winter wheat seedling and radicle ratio after 11 days of sprouting in Petri dish

Note: S – stock solution, Sx2 – two-fold dilution, Sx5 – five-fold dilution, Sx10 – ten-fold dilution, distilled water – control treatment

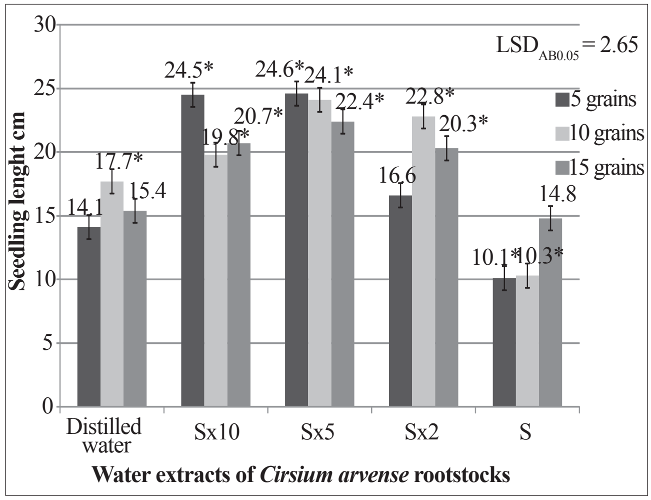

Fig. 6. The effect of *Cirsium arvense* rootstock water extracts on early growth of winter wheat seedling length after eleven days of sprouting

Note: S – stock solution, Sx2 – two-fold dilution, Sx5 – five-fold dilution, Sx10 – ten-fold dilution, distilled water – control treatment; $LSD_{AB0.05}$ – the least significant difference at 95% level of probability; * - significant difference at 95% level of probability ($P < 0.05$) from control treatment – Petri dish with distilled water and 5 grains of winter wheat

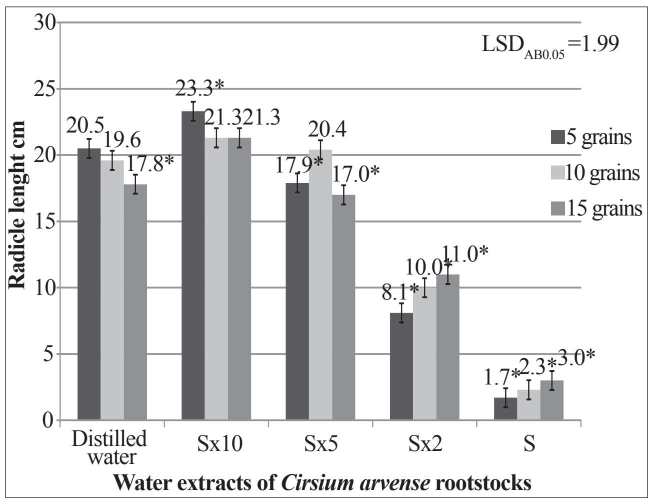

Fig. 7. The effect of *Cirsium arvense* rootstock water extracts on early growth of winter wheat radicle length after eleven days of sprouting

Note: S – stock solution, Sx2 – two-fold dilution, Sx5 – five-fold dilution, Sx10 – ten-fold dilution, distilled water – control treatment; $LSD_{AB0.05}$ – the least significant difference at 95% level of probability; * - significant difference at 95% level of probability ($P < 0.05$) from control treatment – Petri dish with distilled water and 5 grains of winter wheat

Cirsium arvense rootstock (Figures 6 and 7) than its over-ground part (Figures 4 and 5) water extracts. Accordingly, *Cirsium arvense* rootstock water extracts were more phytotoxic to winter wheat seedling and radicle early growth than its over-ground part water extracts.

Shorter winter wheat radicle (Figure 7) than seedling (Figure 6) showed higher negative phytotoxic impact of *Cirsium arvense* rootstock water extracts on it. This regularity was supported by the data of winter wheat seedling and radicle growth ratio (Figure 8). Proportionally, radicle growth either was more inhibited than seedling growth. Winter wheat radicle growth in *Cirsium arvense* rootstock water extracts (Figure 8) was suppressed even more than in *Cirsium arvense* over-ground part water extracts (Figure 5) of stock solution. In lower concentrations of *Cirsium arvense* water extracts environment the ratio of winter wheat seedling and radicle growth was analogous.

Conclusions

Low concentration water extracts of *Cirsium arvense* creeping thistle slightly stimulated *Triticum aestivum* winter wheat grain germination while increasing experimental dilution concentration grain germination was essentially $P < 0.05$ suppressed. *Cirsium arvense* over-ground part was more phytotoxic to the winter wheat grain germination than its rootstock stock solution. Recipient plant concentration (number of winter wheat grains) per *Petri* dish had no significant $P > 0.05$ influence on grain germination intensity.

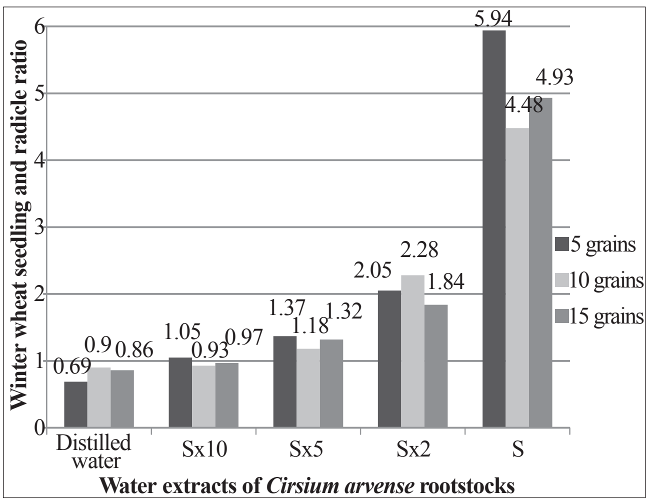

Fig. 8. The effect of *Cirsium arvense* rootstock water extracts on early growth of winter wheat seedling and radicle ratio after eleven days of sprouting in Petri dish

Note: S – stock solution, Sx2 – two-fold dilution, Sx5 – five-fold dilution, Sx10 – ten-fold dilution, distilled water – control treatment

Cirsium arvense over-ground and rootstock water extracts of ten-fold dilution generate minor stressful conditions initiating winter wheat seedling $P < 0.05$ and radicle $P < 0.05$ growth. Increase of *Cirsium arvense* water extracts concentration led to winter wheat radicle length decline $P < 0.05$ while seedling growth was suppressed $P < 0.05$ sustaining longer one (except stock solution) than in distilled water.

Cirsium arvense rootstock water extracts were more phytotoxic to winter wheat seedling and radicle early growth than its over-ground part water extracts while winter wheat radicle as well seedling length was shorter applying *Cirsium arvense* rootstock than its over-ground part water extracts.

Increase in concentration of *Cirsium arvense* regularly increased winter wheat seedling and radicle ratio from 0.87-0.98 to 2.84-3.38 (over-ground water extracts) and from 0.69-0.90 to 4.48-5.94 (rootstock water extracts), showing change from relatively more intensive radicle to seedling growth.

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