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Allelopathic potential of Jimsonweed (*Datura stramonium* L.) on the early growth of maize (*Zea mays* L.) and sunflower (*Helianthus annuus* L.)

Alelopatický potenciál durmanu obyčajného (*Datura stramonium* L.) na skoré štádia rastu kukurice siatej (*Zea mays* L.) a slnečnice ročnej (*Helianthus annuus* L.)

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Abstract

Laboratory and glasshouse experiments were carried out to investigate the allelopathic potential of different plant parts of *D. stramonium* on maize and sunflower on early growth stages. The aqueous leachates of *D. stramonium* roots and shoot did not produc a significant effect on germination and shoot length of maize, but root length of maize was significantly reduced at the highest (1/1) *D. stramonium* roots leachate compared to control. From the other side, germination of sunflower was significantly reduced at the highest (1/1) *D. stramonium* shoot leachate concentration, but lower (1/5 and 1/2) *D. stramonium* roots leachate concentrations significantly increased root and shoot length of sunflower compared to control. In glasshouse experiment, no one treatment with different *D. stramonium* plant residues significantly affected density, height and fresh weight of maize plants compared to control. Contrary*, D. stramonium* mixtures with 1/1 root and shoot residues significantly reduced plants density and fresh weight of sunflower plants compared to control. Lower (1/2 and 1/5) mixtures of *D. stramonium* roots residues and mixture with 1/5 *D. stramonium* shoot residues significantly increased the height of the sunflower plants.

Keywords: allelochemicals, *Datura stramonium* L., maize, sunflower

Abstrakt

Laboratórne a skleníkové pokusy boli vykonávané za účelom skúmania alelopatického potenciálu rôznych častí rastliny *D. stramonium* na kukuricu siatu a slnečnicu ročnú v ich skorých rastových fázach. Vodné výluhy z koreňov a výhonkov *D. stramonium* nevykazovali signifikantný (významný) efekt na klíčenie a dĺžku stonky kukurice siatej, avšak dĺžka koreňov kukurice siatej bola preukazne najviac redukovaná vo variante (1/1) výluh koreňvo *D. stramonium* v porovnaní s kontrolou. Na druhej strane, klíčenie slnečnice ročnej bolo výrazne potlačené najviac pri výluhu z koreňa *D. stramonium* (1/1), ale nižšie pri koncetrácií (1/5 a ½) *D. stramonium* a zárovaň preukazne vzrástla dĺžka koreňa a stonky slnečnice ročnej v porovnaní s kontrolou. V skleníkovom pokuse, žiadne ošetrenie s rozdielnymi reziduami rastlín *D. stramonium* preukazne neovplyvnilo hustotu, výšku a hmotnosť zelenej hmoty rastlín kukuriece siatej v porovnaí s kontrolou. Nižšie koncetrácie reziduí koreňov *D. stramonium* (1/2 a 1/5) a zmes s (1/5) reziduí výhonkov *D. stramonium* preukazne zvýšilo výšku rastlín slnečnice ročnej.

Kľúčové slová: alelochemikálie, *Datura stramonium* L., kukurica siata, slnečnica ročná

Detailný abstrakt

Laboratórne a skleníkové pokusy boli vykonávané za účelom skúmania alelopatického potenciálu rôznych častí rastliny *D. stramonium* na kukuricu siatu a slnečnicu ročnú v ich skorých rastových fázach. Vodné výluhy z koreňov a výhonkov *D. stramonium* nevykazovali signifikantný (významný) efekt na klíčenie a dĺžku stonky kukurice siatej, avšak dĺžka koreňov kukurice siatej bola preukazne najviac redukovaná vo variante (1/1) výluh koreňov *D. stramonium* v porovnaní s kontrolou. Na druhej strane, klíčenie slnečnice ročnej bolo výrazne potlačené najviac pri výluhu z koreňa *D. stramonium* (1/1), ale nižšie pri koncetrácií (1/5 a ½) *D. stramonium* a zárovaň preukazne vzrástla dĺžka koreňa a stonky slnečnice ročnej v porovnaní s kontrolou.

V skleníkovom pokuse, žiadne ošetrenie s rozdielnymi reziduami rastlín *D. stramonium* preukazne neovplyvnilo hustotu, výšku a hmotnosť zelenej hmoty rastlín kukuriece siatej v porovnaí s kontrolou. Nižšie koncetrácie reziduí koreňov *D. stramonium* (1/2 a 1/5) a zmes s (1/5) reziduí výhonkov *D. stramonium* preukazne zvýšilo výšku rastlín slnečnice ročnej.

Dosiahnuté výsledky demonštrujú alelopatický potenciál rôznych častí rastliny *D. tramonium* na skoršie rastové fázy kukurice siatej a slnečnice ročnej a preukazne ovplyvňujú niektoré parametre plodín. V tejto štúdií sa nepreukázal vplyv výluhov *D. stramonium* na skoršie rastové štádia slnečnice a čiastočne aj kukurice v laboratórnych aj skleníkových podmienach. V budúcnosti je nutné zamerať sa na pôsobenie rozličných výluhov koreňa a stonky *D. stramonium,* v rôznej koncetrácií a množstve reziduií, na vývoj rastlín kukurice siatej a slnečnice ročnej v poľných podmienkach.

Introduction

Datura stramonium (Jimsonweed) is erect (0,30 to 1,50 m tall) summer growing annual plant of the family *Solanaceae*. Its status as a weed in many summer crops, partucularly maize, sunflower, cotton, peanuts and soybean, is generally atributed to its ability to compete with crops for moisture, nutritients and light (Cavero et al., 1999; Felton, 1979; Karimmojeni, 2010; Kirkpatrick, 1983; Weaver, 1986; Williams, 1995; Zanin, 1994). Beside this, all its parts, including seeds, contain a terpenoids, phenoloids and alkaloids, principally scopolamine and hyosciamine (Mothes, 1955) with atropine and meteloidine present in smoll amounts (Aplin, 1976), showing significant allelopathic activity (Narwal, 1994), sufficient to inhibit the germination and early radicle growth of many crops (Levitt, Lovett and Garlick, 1984; Lovett and Levitt, 1982; Oudhia, Kolhe and Tripathi, 1996; Oudhia and Tripathi, 1998; Oudhia, Kolhe and Tripathi, 1999; Reting, Holm and Struckmeyer, 1972).

Allelochemicals of *D. stramonium* recovered from field soils at a commercial farm, reduced seedling emergence of many crops (Levitt and Lovett, 1984). For instance, in germinating seeds of *Helianthus annuus* L. the primary effect of *D. stramonium* allelochemicals appears to be retardation of the metabolism of food reserves (Levitt, Lovett and Garlick, 1984), and the secondary effects include reduced germination and early growth of radicles (Levitt and Lovett, 1984; Lovett, Levitt, Duffield and Smith, 1981). Reting et al. (1972) found that *D. stramonium* seeds inhibited cell elongation of the roots of *Brassica oleracea* L. seedlings. The aqueous leachates of different parts of D. *stramonium* produced a significant inhibition effect on germination of chickpea (Oudhia, Kolhe and Tripathi, 1998). The allelochemicals (essential oil and its aqueous saturated solution) from *D*. *stramonium* significantly inhibited the germination and growth of many crops, included maize (You and Wang, 2011). By an increase in *D. stamonium* water leachate concentration a significant reduction in canola and corn germination and radicle and plumule growth was recorded (Shajie, Govahi and Safari, 2009). On the other side, Šćepanović et al. (2007) noticed promoting effect on radicle length of corn by aqueous leachate of *D. stramonium* L.

Understanding the mode of action of an allelochemicals is of particular importance in a weed-crop situation where it may be possible to manipulate the system to the advantage of the crop (Putnam and Duke, 1978). Gross morphological effects, such as a reduction in plant growth resulting from the action of allelochemicals, are general phenomena which may be caused by a variety of more specific effects acting at the cellular or molecular level in the target plant (Rice, 1979).

Therefore, the objective of this study was to evaluate the allelopathic effect of *D. stramonium* L. on the early growth of maize and sunflower, taking into consideration that *D. stramonium* L. is a weed with major economic impact on profitable maize and sunflower production system in Republic of Macedonia.

Materials and methods

Experiments were carried out in the Weed Science laboratory and glasshouse at the Faculty of Agriculture Sciences and Food in Skopje during 2011, to explore the allelopathic potential of different plant parts of *D. stramonium* on maize and sunflower early growth. For that purpose, fresh plants of *D. stramonium* were collected at the buttonization (budding) stage (end of August) from the faculty experimental field in Trubarevo, Skopje region, Republic of Macedonia.

Laboratory experiment

From freshly collected *D. stramonium* plants, roots and shoots were separated, cut into small pieces and put in a grinder. After grinding, 100 g fresh roots and 100 g fresh shoots, respectively, was soaked each into 1000 ml distilled water (1:10 ratio w/v) for 24 h at room temperature. After 24 hours, plant material was removed and leachates were filtered through filter paper (MN 640w). Three aqueous leachate concentrations (1/1, 1/2 and 1/5) were used in the experiment, which was carried out in Petri dishes. In each sterilized Petri dish wetting of two filter paper layers, by 25 seeds of maize and sunflower were sowed in three replicates. After sowing, by 8 ml different aqueous leachates (1/1, 1/2 and 1/5) were added per Petri dish. For the control treatment, distilled water was used. The Petri dishes were incubated in the dark at 20 ±2 °C in a germinator. Germination percentage for both crop seeds was recorded at 4 and 7 days after sowing (DAS). At 11 DAS, root and shoot length of both crops in each leachate concentrations were measured and compared with the control.

Greenhouse experiment

After separation, roots and shoots of *D. stramonium* were cut into small pieces and air-dried in the glasshouse conditions for 7 days. 2 kg of dried roots and 2 kg of dried shoots, respectively, were mixed each in 20 kg soil (Fluvisol sandy loam with 10.50 % coarse, 63.10 % fine sand, 26.40 % clay+silt, 2.66 % organic matter and pH 6.7) + manure, in a ratio of 1:1, and were kept in glasshouse conditions with adding by 5 l water per week. After 90 days of decomposition, soil mixture containing roots and shoots residues of *D. stramonium*, respectively, were obtained. Three soil mixture concentrations (1/1, 1/2 and 1/5) were used in the glasshouse experiment, which was carried out in plant growing containers (170 x 250 x 110 mm). For the control treatment, only soil + manure (in a ratio of 1:1 and without *D. stramonium* residues) were used. Three replicates of 30 seeds of maize and sunflower were sowed in each plant growing containers. After sowing, the plant growing containers were kept in glasshouse conditions and irrigated during all experiment period. Maize and sunflower plants were collected 30 days after sowing (DAS). Data were recorded on the following parameters: maize/sunflower density, height and fresh weight per container. Maize/sunflower plant density and height were recorded before plants collecting, and fresh weight of the maize/sunflower plants was recorded 30 DAS. Comparison of maize/sunflower parameters was made between control and different soil mixture concentrations. Finally, the data of both experiments were subjected to statistical analysis applying LSD-test (Steel, Torrie and Dicky, 1997).

Results and discussion

Laboratory experiment with maize

At 4 and 7 DAS, the lower (1/2 and 1/5) *D. stramonium* roots aqueous leachates showed stimulatory effect on the seed germination of maize for both periods (85.3 and 100 %; 84 and 98.7 %, respectively) compared to control (80.0 and 96.0%) (Table 1). Also, increasing of the seed germination of maize for both periods was recorded at the lowest (1/5) *D. stramonium* shoots leachate concentration (82.7 and 98.7 %) compared to control (80.0 and 96.0 %) (Table 1). Results of Šćepanović et al. (2007) showed that germination of maize, measured 3, 6 and 10 days after treatments, was inhibited by aqueous leachates of above ground part of plants of *D. stramonium* in average for 10.2 %. From the other side, 0.1 and 0.2 mg*ml^{-1} alkaloid extracts of *D. stramonium* improve the seed germination of *Cicer arietium* L., but 0.3 and 0.6 mg*ml^{-1} showed restrictive effect on the seed germination of the same crop (Zheng, Li, Lu and Ren, 2007). Similar results were obtained by Zheng and Li (2008), who concluded that 0.1 mg*ml^{-1} alkaloid leachates of *D. stramonium* promoted the seed germination of the maize and above 0.2 mg*ml^{-1} leachate of alkaloids of *D. stramonium* decreased seed germination, activity of α-amylase, seeds germination rate, germination index and vigour index of maize. 0.4 g*ml^{-1} extracted liquid from *D. stramonium* roots decreased seed germination of sesame and millet by 31.2 % and 56.2 %, respectively, in comparison with the control (Wang, Cheng, Yuan, Fang and Song, 2009). Similar, scopolamine plus hyoscyamine at the 1:1 concentration gave a relatively greater depression of *L. usitatissimum* germination (Lovett, Levitt, Duffield and Smith, 1981).

Root length of maize was significantly reduced only at the highest (1/1) *D. stramonium* roots leachate concentration (20.3 cm) relative to control (27.0 cm) and other lower (1/2 and 1/5) leachate concentrations (25.0 and 28.7 cm, respectively) (Table 1). Lovett et al. (1981). showed that scopolamine and scopolamine plus hyoscyamine (1:1 concentration) depressed linseeds radicle elongation significantly below that of the control. Abenavoli et al. (2004) reported that coumarin at 0.25 mM stunted radicle, seminal and nodal root lengths of maize by 50 %. Higher doses of coumarin caused swelling of the subapical root zone of maize. 0.4 g/mL extracted liquid from *D. stramonium* stems decreased root length of sesame and millet seedling by 93.3 % and 64.7 %, respectively, compared to control (Wang, Cheng, Yuan, Fang and Song, 2009). Opposite, the aqueous leachate of fresh shoots and leaves of *D. stramonium* increased maize radicle length for 35.7 % compared to control (Šćepanović, Novak, Barić, Ostojić, Galzina and Goršić, 2007). Results obtained by Oudhia et al. (1998) indicated the possibility of utilizing the *D. stramonium* stem + leaf leachate of 11 days for presowing soaking treatment of chickpea in order to achieve better root elongation, without affecting germination.

Increasing of shoot length was recorded at the lowest (1/5) *D. stramonium* roots leachate concentration (126 mm) and all (1/1; 1/2; 1/5) *D. stramonium* shoots leachate concentrations (128; 138 and 140 mm, respectively) compared to control (125 mm) (Table 1). These results are contradictory to (Šćepanović et al., 2007) who found that the aqueous leachate of fresh shoots and leaves of *D. stramonium* decreased maize shoot length for 27.8 % compared to control. Further, 0.2 mg*ml^{-1} leachate of *D. stramonium* alkaloids inhibited seedling growth of maize, seedling height, α-amylase activity, and the contents of chlorophyll and protein (Zheng and Li 2008).

Laboratory experiment with sunflower

Germination of sunflower was significantly reduced 4 and 7 DAS at the highest (1/1) *D. stramonium* shoots leachate concentration (68.0 and 70.7 %, respectively) relative to control (81.3 and 84.0 %, respectively) (Table 2). These results are supported by Kazinczi et al. (2004). They found 86 % reduction of sunflower germination due to water leachates of *D. stramonium* shoots. Similar strong inhibitory effect was observed earlier by Beres and Kazinczi (2000).

From the other side, all *D. stramonium* roots leachate concentrations showed stimulatory effect on root length of sunflower, but only lower (1/2 and 1/5) *D. stramonium* roots leachate concentrations significantly increased root length of sunflower (116 and 134 mm, respectively) compared to control (85 mm). Stimulatory effect on root length of sunflower was recorded to all *D. stramonium* shoots leachate concentration, as well (Table 2).

Table 1. Allelopathyc effect of *Datura stramonium* L. on the early growth of maize
Tabuľka 1. Alelopatický účinok *Datura stramonium* L. na začiatku rastu kukurice siatej

	Datura stramonium root leachates				*Datura stramonium* shoot leachates			
Treatments	Germination (%)		Root length (mm)	Shoot length (mm)	Germination (%)		Root length (mm)	Shoot length (mm)
	4 DAS	7 DAS			4 DAS	7 DAS		
Control	80.0 a	96.0 ab	270 ab	125 a	80.0 a	96.0 a	270 a	125 a
Filtrate (1/1)	78.7 a	93.3 b	203 c	117 a	66.7 a	86.7 a	252 a	128 a
Filtrate (1/2)	85.3 a	100.0 a	250 b	113 a	78.7 a	88.0 a	263 a	138 a
Filtrate (1/5)	84.0 a	98.7 ab	287 a	126 a	82.7 a	98.7 a	273 a	140 a
LSD (5%)	16.90	5.49	30.9	12.7	18.21	12.28	46.2	22.2

Means with the same letter in a column are not significantly different at 5% probability level

Table 2. Allelopathyc effect of *Datura stramonium* L. on the early growth of sunflower
Tabuľka 2. Alelopatický účinok Datura stramonium L. na začiatku rastu slnečnice ročnej

	Datura stramonium root leachates				*Datura stramonium* shoot leachates			
Treatments	Germination (%)		Root length (mm)	Shoot length (mm)	Germination (%)		Root length (mm)	Shoot length (mm)
	4 DAS	7 DAS			4 DAS	7 DAS		
Control	81.3 a	84.0 a	85 a	96 b	81.3 a	84.0 a	85 a	96 b
Filtrate (1/1)	77.3 a	84.0 a	90 a	109ab	68.0 b	70.7 b	86 a	115 ab
Filtrate (1/2)	80.0 a	80.0 a	116 b	122 a	73.3 a	76.0 a	108 a	112 ab
Filtrate (1/5)	82.7 a	84.0 a	134 b	128 a	76.0 a	80.0 a	93 a	124 a
LSD (5%)	*14.53*	*8.94*	*25.7*	*25.2*	*11.61*	*10.32*	*24.5*	*24.8*

Means with the same letter in a column are not significantly different at 5% probability level

Trend of stimulatory effect of *D. stramonium* plant leachates on the early growth of sunflower was recorded on sunflower shoot length, as well. All *D. stramonium* roots leachates showed stimulatory effect on shoot length of sunflower, but only lower (1/2 and 1/5) *D. stramonium* roots leachate concentrations significantly increased shoot length of sunflower (122 and 128 mm, respectively) compared to control (96 mm). Stimulatory effect on shoot length of sunflower was recorded to all *D. stramonium* shoots leachate concentrations, as well, but only 1/5 *D. stramonium* shoot leachate concentration significantly increased shoot length of sunflower (124 mm) compared to control (96 mm) (Table 2).

Greenhouse experiment with maize

The emergence of maize and sunflower in all treatments took place between 4 and 7 DAS, thus, germination was not affected by any *D. stramonium* roots and shoots residue mixtures.

The number of maize plants per growing containers filled with different mixtures of *D. stramonium* root residues ranged between 27.7 (mixture with 1/1 root residues) and 29.0 (mixture with 1/2 root residues). Similar situation was noted to the treatments with different *D. stramonium* shoots residues. The highest maize density was recorded to containers with 1/5 shoots residues (29.0), followed by 1/2 shoots residues (28.0). The lowest maize density was recorded in containers filled with the mixture with 1/1 shoots residues (25.3) (Table 3).

The height of the maize plants was not significantly reduced by any *D. stramonium* plant residues mixtures (Table 3). The tallest maize plants in the mixtures with different *D. stramonium* root residues (402 mm) were recorded in containers with 1/5, followed by 1/2 (394 mm), while the shortest maize plants (387 mm) was recorded in containers with 1/1 *D. stramonium* root residues. Similar situation was noted to the treatments with different *D. stramonium* shoot residues (Table 3). Dzyubenko and Petrenko (1971) investigated the interactions between two weed species, *Chenopodium album* L. and *Amaranthus retroflexus* L. and two crop species, *Lupinus albus* L. and *Zea mays* L. According them, that exudates of the roots of weed species stimulated growth of cultivated plants.

Fresh weight of the maize plants depended on the previous parameters: density and height of maize plants. Highest fresh weight in the mixtures with different *D. stramonium* root residues (117.2 g) was measured in containers with 1/2, while the lowest fresh weight (108.7 g) was measured in containers with 1/1 *D. stramonium* root residues. Similar situation was noted to the treatments with different *D. stramonium* shoot residues. Highest fresh weight (116.2 g) was measured in containers with 1/5, while the lowest fresh weight (107.5 g) was measured in containers with 1/1 *D. stramonium* shoot residues (Table 3). These results are contradictory to Soufan and Almouemar (2009) who found that aqueous leachate of *C. rotundus*, *C. arvensis* and *S. halepense* at the concentration of 20 % and 80 % significantly inhibited plant height and fresh and dry weight of maize. Apart from their inhibitory effects, allelochemicals of *Cyperus, Setaria, Agropyron*, increased the growth and yield of many crops, including maize (Bhowmik and Doll, 1982; Chivinge, 1985; Hagin, 1989). In contrast, the aqueous leachate of *Mikania micrantha* H.B.K. did not affected the fresh weight of long bean and corn (Ismail and Chong, 2002).

Greenhouse experiment with sunflower

Regarding density of sunflower plants, statistical analysis of the data (Table 4) revealed that only *D. stramonium* mixtures with 1/1 root and shoot residues (23.7 and 24.0, respectively) significantly affected sunflower plants density compared to control (26.7) (Table 4).

Except the highest (1/1), lower (1/2 and 1/5) mixtures of *D. stramonium* roots residues significantly increased the height of the sunflower plants (240 and 241 mm, respectively) compared to control (214 mm). Similar increasing effect on the height of the sunflower plants was recorded to lower (1/2 and 1/5) mixtures of *D. stramonium* shoot residues, but only mixture with 1/5 *D. stramonium* shoot residues significantly increased height of the sunflower plants (242 mm) compared to control (214 mm) (Table 4). Results of Shajie and Saffari (2009) indicated that plant residues of *D. stramonium* reduced height, leaf area and dry weight of canola.

Table 3. Allelopathyc effect of *Datura stramonium* L. on the maize growth parameters
Tabuľka 3. Alelopatický účinok *Datura stramonium* L. na rastové parametre kukurice siatej

	Datura stramonium root leachates			*Datura stramonium* shoot leachates		
Treatments	Plant density	Height of the plants (mm)	Fresh weight of the plants/ container (g)	Plant density	Height of the plants (mm)	Fresh weight of the plants/ container (g)
Control	28.3 a	395 a	116.1 a	28.3 a	395 a	116.1 a
Mixture (1/1)	27.7 a	387 a	108.7 a	25.3 ab	376 a	107.5 a
Mixture (1/2)	29.0 a	394 a	117.2 a	28.3 a	390 a	113.3 a
Mixture (1/5)	28.7 a	402 a	116.4 a	29.0 ac	394 a	116.2 a
LSD (5%)	3.03	31.3	8.80	3.11	28.3	10.96

Means with the same letter in a column are not significantly different at 5% probability level

Table 4. Allelopathyc effect of *Datura stramonium* L. on the sunflower growth parameters
Tabuľka 4. Alelopatický účinok *Datura stramonium* L. na rastové parametre slnečnice ročnej

	Datura stramonium root leachates			*Datura stramonium* shoot leachates		
Treatments	Plant density	Height of the plants (mm)	Fresh weight of the plants/ container (g)	Plant density	Height of the plants (mm)	Fresh weight of the plants/ container (g)
Control	267 a	214 b	96.2 a	267 a	214 b	96.2 ac
Mixture (1/1)	237 b	194 b	85.7 b	240 b	198 b	87.6 b
Mixture (1/2)	260 a	240 a	100.3 a	250 ab	223 ab	93.8 ab
Mixture (1/5)	263 a	241 a	102.9 a	260 a	242 a	101.5 ac
LSD (5%)	26.8	26.3	7.02	20.8	26.0	7.23

Means with the same letter in a column are not significantly different at 5% probability level

Fresh weight of the sunflower plants was significantly reduced at the highest (1/1) mixtures of *D. stramonium* roots and shoot residues (85.7 and 87.6 g, respectively) compared to control (96.2 g). Kazinczi et al. (2004) investigated the allelopathyc influence of few weed species on maize development. They observed that shoot residues of *Asclepias syriaca* and *Datura stramonium* significantly promoted fresh weight of sunflower.

Conclusion

Obtained results demonstrated the allelopathic potential of the different plant parts of *D. stramonium* on maize and sunflower early growth, and suggest that they may significantly affect some crop parameters. In this study the effects of them on sunflower and particularly on maize early growth in laboratory and glasshouse conditions were not significant.

Further investigations are necessary in order to investigate behavior of different *D. stramonium* roots and shoots leachate concentrations and residues on maize and sunflower development under field conditions.

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