

Allelopathic potential of some invasive plant species occurring in Hungary

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ABSTRACT

This study aimed to determine the allelopathic potential of some invasive plant species occurring in Hungary. Juglone index of 14-alien woody- and 20-alien herbaceous plant species was determined to compare the effects of juglone and leachates of plant species on germination and seedling growth (shoot length, root length) of white mustard (*Sinapis alba* L.) used as receiver species. The leachates significantly inhibited the root length of test plant. The juglone index at higher concentration leachates of most species was near to 1 or above 1 i.e. the effect of leachates was similar to or higher than juglone. Leachates of 21-plants [*Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle, *Ambrosia artemisiifolia* L., *Amorpha fruticosa* L., *Asclepias syriaca* L., *Celtis occidentalis* L., *Echinocystis lobata* (Michx.) Torr. et Gray, *Fallopia japonica* (Houtt.) Ronse Decr., *Fraxinus pennsylvanica* Marsh. var. *subintegerrima* (Vahl) Fern., *Helianthus tuberosus* L., *Heracleum mantegazzianum* Somm. et Lev., *Impatiens balfourii* Hook. f., *Impatiens glandulifera* Royle, *Impatiens parviflora* DC., *Juglans nigra* L., *Parthenocissus inserta* (A. Kern) Fritsch, *Phytolacca esculenta* van Houtte, *Prunus serotina* Ehrh., *Ptelea trifoliata* L., *Rudbeckia hirta* L. and *Vitis riparia* Michx] reduced the germination and seedling growth (shoot and root length) of *S. alba* L. than control.

Key words: Allelopathy, bioassay, germination, growth inhibition, invasive plant species, juglone index, *Sinapis alba*

INTRODUCTION

Allelopathy is known since ancient times and its inhibitory effects are attributed to secondary metabolites (48). After introducing the term of allelopathy by Molish (39), definition has undergone several changes (5,8). Nowadays it refers to positive or negative, direct or indirect effect by one plant, fungus or microorganisms to the other through the production of chemical compounds that escape into the environment (48,63). Most observations of allelopathy have been related to agriculture and several weeds are allelopathic to crops (3,24,28,29,32,47). However, some plant species allelopathic to weeds can offer a selective and environmentally friendly weed biocontrol (17,36,37,40,42,52). Finding the allelopathic cultivars and genotypes (10,43,44,64), locating the gene responsible for allelopathic effect (64) and using allelochemicals as herbicide (11,19,20,34,35,38,62) are the major research topics.

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Many alien species are allelopathic, hence, able to invade new areas. They have chemicals to which native plants are less resistant. The native species living close to each have to adapt to metabolites produced by the other species during the evolution. Callaway and Aschehoug (6) demonstrated that in North America invasive Eurasian diffuse knapweed (*Centaurea diffusa* Lam.) had much stronger negative effect on studied North American species than it had on native Eurasian species, namely it produces allelochemicals to which Eurasian neighbours have adapted to, but its new North American neighbours have not. During the establishment and spread of invasive plants, allelopathy may be an effective advantage against the other plants, many studies suggest that allelopathy contributes the ability of an alien species to become dominant in invaded plant communities (1,15,16,22,31,45,50).

Several invasive plant species in Hungary are allelopathic (3,4,7,12,13,41,57,60). This study aimed to compare the allelopathic potential of invasive plant species by the method of juglone index.

MATERIALS AND METHODS

Juglone index was chosen to study the allelopathic potential of invasive plant species. Juglone is a strong allelopathic naphthoquinone found in Persian walnut (*Juglans regia* L.), black walnut (*Juglans nigra* L.) and many species of *Juglandaceae* family. It can be washed into the soil by rain from leaves, branches, stem etc. (12,46). Juglone inhibits the germination, growth and development of several plant species (14,31,51,55,56,59), by reducing the photosynthesis and respiration (21,27) and increasing oxidative stress (54).

Method of juglone index was introduced by Szabó (58), it is based on comparing the effects of treatment with 1 mM juglone and leachate of plant species with unknown allelopathic potential. Juglone index is based on the germination (%), shoot length and root length of white mustard (*Sinapis alba* L.) treated with juglone and leachate of unknown allelopathic potential. If the juglone index is > 1, the allelopathic inhibition is stronger, if it is < 1, the allelopathic inhibition is weaker (58). The juglone index ($I_{j/x}$) of leachate with unknown allelopathic potential was calculated as under:

$$I_{j/x} = (H_j + R_j + G_j) / (H_x + R_x + G_x)$$

Where, H_j or H_x : Mean shoot length (mm) of white mustard seeds treated with 1 mM juglone or leachate of donor species (mm), R_j or R_x : Mean root length (mm) of white mustard seeds treated with 1 mM juglone or leachate of donor species, G_j or G_x : Mean germination (%) of white mustard seeds treated with 1 mM juglone or leachate of donor species (number).

For this study shoots of 14 woody and 20 herbaceous alien plant species (Table 1) were collected from their natural habitats and dried at room temperature. The experimental treatments consisted of two factors (i). Leachate concentrations: 3 (0,1,5%)

Table 1. Juglone index of studied alien plant species

Alien plant species	English name	Invasive status in Hungary	Juglone index	
			1 % leachate	5 % leachate
Woody species				
<i>Juglans nigra</i> L.	Black walnut	Casual	0.80	1.08
<i>Morus alba</i> L.	White mulberry	Casual	0.80	0.86
<i>Ptelea trifoliata</i> L.	Common hoptree	Naturalized	0.73	1.03
<i>Prunus serotina</i> Ehrh.	Black cherry	Invasive	0.77	1.04
<i>Ribes aureum</i> Pursh	Golden currant	Invasive	0.77	0.91
<i>Amorpha fruticosa</i> L.	False indigo	Transformer	1.11	2.00
<i>Ailanthus altissima</i> (Mill.) Swingle	Tree-of-heaven	Transformer	0.80	1.49
<i>Celtis occidentalis</i> L.	Common hackberry	Transformer	0.86	1.36
<i>Robinia pseudoacacia</i> L.	Black locust	Transformer	0.84	1.01
<i>Fraxinus pennsylvanica</i> var. <i>subintegerrima</i> (Vahl) Fern.	Green ash	Transformer	0.76	1.01
<i>Acer negundo</i> L.	Box elder	Transformer	0.93	0.99
<i>Parthenocissus inserta</i> (A. Kern) Fritsch	Thicket creeper	Transformer	0.76	0.96
<i>Vitis riparia</i> Michx.	Frost grape	Transformer	0.81	0.94
<i>Elaeagnus angustifolia</i> L.	Russian olive	Transformer	0.74	0.93
<i>Fraxinus pennsylvanic</i> var. <i>austini</i> Fern.	Northern red ash	Transformer	0.79	0.85
Herbaceous species				
<i>Impatiens balfourii</i> Hook. f.	Balfour's touch-me-not	Casual	0.92	1.25
<i>Rudbeckia hirta</i> L.	Black-eyed Susan	Casual	0.77	1.03
<i>Thladiantha dubia</i> Bunge	Goldencreeper	Naturalized	0.86	0.97
<i>Phytolacca esculenta</i> van Houtte	Indian pokeweed	Invasive	0.91	5.49
<i>Impatiens parviflora</i> DC.	Small balsam	Invasive	1.05	1.17
<i>Rudbeckia laciniata</i> L.	Cutleaf coneflower	Invasive	0.78	1.15
<i>Erigeron annuus</i> (L.) Pers.	Annual fleabane	Invasive	0.86	0.89
<i>Heracleum mantegazzianum</i> Somm. et Lev.	Giant hogweed	Transformer	0.99	3.10
<i>Impatiens glandulifera</i> Royle	Himalayan balsam	Transformer	0.83	1.27
<i>Fallopia x bohemica</i> (Chrték & Chrtková)	Bohemian knotweed	Transformer	0.97	1.06
<i>Fallopia japonica</i> (Houtt.) Ronse Decr.	Japanese knotweed	Transformer	0.95	1.06
<i>Phytolacca americana</i> L.	American pokeweed	Transformer	0.93	1.05
<i>Asclepias syriaca</i> L.	Common milkweed	Transformer	0.82	1.02
<i>Helianthus tuberosus</i> L. s.l.	Jerusalem artichoke	Transformer	0.87	0.98
<i>Echinocystis lobata</i> (Michx.) Torr. et Gray	Wild cucumber	Transformer	0.83	0.98
<i>Solidago canadensis</i> L.	Canadian goldenrod	Transformer	0.87	0.97
<i>Aster lanceolatus</i> agg. Willd.	Lance-leaved aster	Transformer	0.73	0.96
<i>Solidago gigantea</i> Ait.	Giant goldenrod	Transformer	0.89	0.93
<i>Ambrosia artemisiifolia</i> L.	Common ragweed	Transformer	0.86	0.93
<i>Conyza canadensis</i> (L.) Cronq.	Canadian fleabane	Transformer	0.84	0.90

Invasive status of species is as per the current list of Hungarian neophytes (2).

Casual plants: These are alien plants that do not form self-replacing populations, but may flourish and reproduce occasionally. **Naturalized plants:** These reproduce consistently and sustain populations without direct intervention by humans. **Invasive plants:** These are naturalized species producing reproductive offspring at considerable distances from parent plants. **Transformers:** These are invasive plants which change the character, condition, form or nature of ecosystems considerably (49).

and (ii). Donor spp. 34 (Table 1). The distilled water served as control. Most of the studied plants were invasive transformer species; few were invasive-, naturalized- or casual species but they could become invasive or transformer species (2) in future (Table 1). According to Richardson *et al.* (49), 'Casual plants' are alien plants that do not form self-replacing populations, but may flourish and reproduce occasionally. 'Naturalized plants' reproduce consistently and sustain populations without direct intervention by humans; 'invasive plants' are naturalized species producing reproductive offspring at considerable distances from parent plants; 'transformers' are invasive plants which considerably change the character, condition and nature of ecosystems (49). Aqueous leachates were prepared as per Szabó (58), by soaking 1 g and 5 g chopped plant materials of donor species in 100 ml distilled water at 20 °C for 1.0 h, shaken for 10 min and filtered through filter paper. One hundred white mustard seeds were placed in each 10 cm dia Petri dishes. White mustard seeds were germinated between two filter papers wetted with 5 ml leachate, in dark, placed in incubator at 20 °C. Each treatment was replicated thrice. Germination (%), shoot and root length were recorded 6 day after sowing.

The major allelopathic compound of tree-of-heaven was identified as quassinoid called aianthone (19). Lodhi (33) identified scopolin, scopoletin, caffeic acid, ferulic acid and p-coumaric acid from common hackberry leaf aqueous extracts and proved their inhibitory effect on germination and radicle growth of *Bromus tectorum* L. Horsley (23) reported allelopathic effect of benzoic acid, derived from benzaldehyde during prunasin catabolism in black cherry leaves to *Acer rubrum* L. seedlings. False indigo significantly inhibited the seedling growth of soybean through its aqueous extract which contained formic acid, propionic acid, 2-methylphenol, 2-methyl-4-pentenoic acid, succinic acid, D-limonene, salicylic acid, 4-hydroxybenzoic acid, cinnamin acid, 3-phenylpropionic acid, DL-tartaric acid, 3,4-dihydroxybenzoic acid, umbelliferone, 4-coumaric acid, 7-methoxyxoumarine, syringic acid, palm acid (18).

Field Study

Five invasive woody species [tree-of-heaven (*Ailanthus altissima* (Mill) Swingle, common hackberry (*Celtis occidentalis* L.), false indigo (*Amorpha fruticosa* L.), black cherry (*Prunus serotina* Ehrh.) and black walnut (*Juglans nigra* L.)] with highest juglone index were further evaluated under field conditions. These invasive alien species have heavily infested the Hungarian forests of one of the most important native tree species (*Quercus robur* L.). This field study aimed to answer, if the leaf litter of these 5- invasive species affect the growth and development of oak and cause any problem for forestry. Shoots of 5-invasive woody plant species were collected from their natural habitats in 2010 and dried at room temperature. Dried plant materials (1.5 kg for 20 m²) were mixed in the upper soil layer of oak plantation in May 2011. Effects of 5- invasive donor spp were measured 6-times (June 27, July 13, August 5, August 23, September 13 and October 5 2011) on the height and shoot diameter of 100 oak seedlings.

Statistical Analysis

Results were evaluated using Chi-square test in germination (%) and Mann-Whitney test in height, root length, shoot length and diameter (26). InStat statistical programme [extremely significant (P<0.001), very significant (P<0.01), significant (P<0.05), not quite significant (P≤0.1), not significant (P>0.1)] were used for statistical analysis of data.

RESULTS AND DISCUSSION

The juglone index at higher concentration leachates (5 g dry plant material leached with 100 ml distilled water) of almost every studied species approaches to 1 or is above 1. Lower juglone index belonged to lower concentration leachates than to higher concentration leachate in case of every species, although this difference was more considerable by species having a higher juglone index. In terms of juglone index, the allelopathic potential of Indian pokeweed (*Phytolacca esculenta* van Houtte), giant hogweed (*Heracleum mantegazzianum* Somm. et Lev.), false indigo (*Amorpha fruticosa* L.), tree-of-heaven (*Ailanthus altissima* (Mill.) Swingle) and common hackberry (*Celtis occidentalis* L.) were the highest (Table 1). These species are all invasive and except for Indian pokeweed are transformers too.

Species can be ranked based on their allelopathic potential using the juglone index at different concentrations of leachates, but it does not give any information about how species inhibit growth and development of test plant. To find this out we compared germination (%), shoot and root length data to control (distilled water only) (Table 2). Chi-square test showed significant inhibitory effects of 31 species on germination of test plant. This inhibitory effect expressed at both concentrations of 14 species. Among woody species false indigo and tree-of-heaven, among herbaceous species giant hogweed and Indian pokeweed had the highest inhibitory effects on the test plant, the later species reduced the germination with 80 %. Golden currant (*Ribes aureum* Pursh) and white mulberry (*Morus alba* L.) showed small-scale but not significant stimulatory effects.

Analyzing the shoot length data the effects of various species and concentrations divided more considerably: only 20 species produced leachates causing significant inhibition on the test plant. Species with highest juglone index such as Indian pokeweed (*Phytolacca esculenta* van Houtte), giant hogweed (*Heracleum mantegazzianum* Somm. et Lev.), false indigo (*Amorpha fruticosa* L.), tree-of-heaven (*Ailanthus altissima* (Mill.) Swingle) and common hackberry (*Celtis occidentalis* L.) had the strongest inhibitory effect which exceeded the 50 %. Golden currant (*Ribes aureum* Pursh), Canadian fleabane (*Conyza canadensis* (L.) Cronq.) and Goldencreeper (*Thladiantha dubia* Bunge) insignificantly stimulated the shoot growth. The root lengths influenced with treatment using different species and concentrations brought more unified results. Leachates of all species at both concentrations significantly reduced the root length.

Results have proven a varied level of allelopathic potential in all species tested. Leachates caused more inhibitory effects on root growth than on shoot growth and germination (%). The juglone index at higher concentration leachates of almost every studied species approaches to 1 or is above 1, this means the inhibitory effect of leachates is similar or stronger than juglone's. Treatment with leachates of *A. negundo*, *A. altissima*, *A. artemisiifolia*, *A. fruticosa*, *A. syriaca*, *C. occidentalis*, *E. lobata*, *F. japonica*, *F. pennsylvanica* var. *sub.*, *H. tuberosus* s.l., *H. mantegazzianum*, *I. balfourii*, *I. glandulifera*, *I. parviflora*, *J. nigra*, *P. inserta*, *P. esculenta*, *P. serotina*, *P. trifoliata*, *R. hirta* and *V. riparia* significantly reduced the germination (%), shoot and root length of test plant, compared to the control.

Table 2. Inhibitory (-) and stimulatory (+) effects of leachates of studied alien plant species on germination and seedling growth of *Sinapis alba* L. (%)

Alien plant species	Inhibition and stimulation (%) over control		
	Germination	Seedling growth	
		Shoot length	Root length
Woody species			
<i>Ribes aureum</i> Pursh	+0.3	+1.3	-50.0
<i>Morus alba</i> L.	+0.3	-4.9	-33.7
<i>Amorpha fruticosa</i> L.	-45.5	-68.1	-85.6
<i>Ailanthus altissima</i> (Mill.) Swingle	-31.8	-50.6	-75.3
<i>Fraxinus pennsylvanica</i> var. <i>subintegerrima</i> (Vahl) Fern.	-14.7	-27.7	-38.1
<i>Celtis occidentalis</i> L.	-14.4	-66.6	-82.7
<i>Juglans nigra</i> L.	-10.7	-30.5	-59.0
<i>Ptelea trifoliata</i> L.	-7.4	-19.3	-59.2
<i>Prunus serotina</i> Ehrh.	-6.0	-27.4	-59.9
<i>Vitis riparia</i> Michx.	-4.7	-14.2	-42.3
<i>Robinia pseudoacacia</i> L.	-3.0	-14.5	-61.9
<i>Acer negundo</i> L.	-2.3	-22.8	-57.0
<i>Parthenocissus inserta</i> (A. Kern) Fritsch	-1.7	-17.4	-51.8
<i>Elaeagnus angustifolia</i> L.	-0.3	-2.8	-53.3
<i>Fraxinus pennsylvanic</i> var. <i>austini</i> Fern.	-0.3	-4.3	-27.9
Herbaceous species			
<i>Phytolacca esculenta</i> van Houtte	-80.3	-79.6	-97.9
<i>Heracleum mantegazzianum</i> Somm. et Lev.	-69.3	-73.5	-85.9
<i>Rudbeckia laciniata</i> L.	-34.2	-18.1	-39.1
<i>Impatiens glandulifera</i> Royle	-26.5	-29.1	-65.4
<i>Impatiens baldouirii</i> Hook. f.	-20.7	-43.5	-66.6
<i>Fallopia x bohemica</i> (Chrték & Chrtková)	-14.1	-6.2	-57.9
<i>Asclepias syriaca</i> L.	-13.7	-27.5	-41.7
<i>Rudbeckia hirta</i> L.	-13.1	-35.9	-43.5
<i>Helianthus tuberosus</i> L. s.l.	-12.7	-25.5	-35.3
<i>Phytolacca americana</i> L.	-9.7	-7.3	-63.7
<i>Solidago gigantea</i> Ait.	-9.7	-1.9	-37.4
<i>Fallopia japonica</i> (Houtt.) Ronse Decr.	-8.7	-24.1	-60.5
<i>Impatiens parviflora</i> DC.	-8.4	-27.4	-58.0
<i>Aster lanceolatus</i> agg. Willd.	-7.7	-6.9	-45.6
<i>Ambrosia artemisiifolia</i> L.	-7.1	-3.8	-40.7
<i>Solidago canadensis</i> L.	-6.4	-7.3	-49.7
<i>Erigeron annuus</i> (L.) Pers.	-4.4	-3.5	-34.0
<i>Thladiantha dubia</i> Bunge	-4.1	+11.8	-62.0
<i>Echinocystis lobata</i> (Michx.) Torr. et Gray	-3.7	-43.5	-43.3
<i>Conyza canadensis</i> (L.) Cronq.	-3.1	+9.7	-33.6

It is known, that Petri dishes bioassays could greatly overestimate the allelopathic effect compared to realistic field conditions (30,61), and to provide strong evidence of allelopathy field studies are necessary (25). The actual importance of allelopathic inhibition caused by invasive or coloniser plants has rarely been demonstrated under natural conditions (32). In our field study mixed dry plant materials of five invasive woody species in the soil, did not show any significant difference neither in shoot diameter nor in

height of pedunculate oak seedlings (Figure 1,2). In the first three month after the treatment the shoot diameters of pedunculate oak seedlings formed near to control or below the control in all donor species. After 5-months the shoot diameters differed positively by treatment of tree-of-heaven, false indigo and black walnut and negatively by treatment of common hackberry and black cherry; but all differences were insignificant. Except for black cherry in the case of all donor species the height of pedunculate oak seedlings increased in the last two months of experiment.

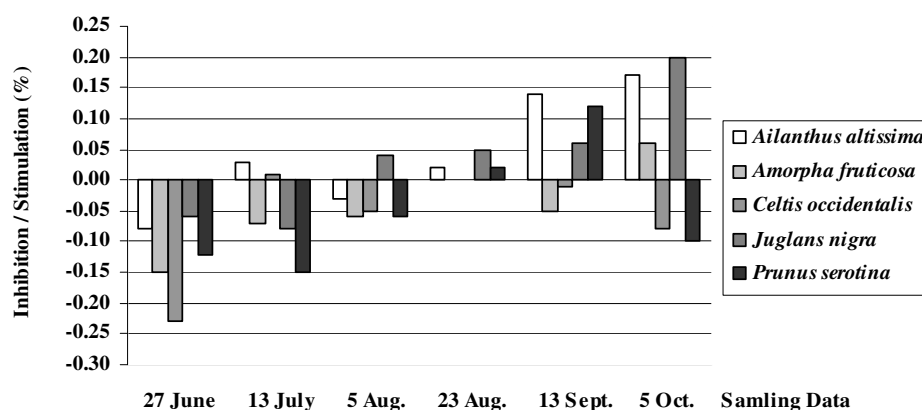


Figure 1. Effects of dried plant materials of 5- invasive woody plant species on shoot diameter of *Quercus robur* L. over control

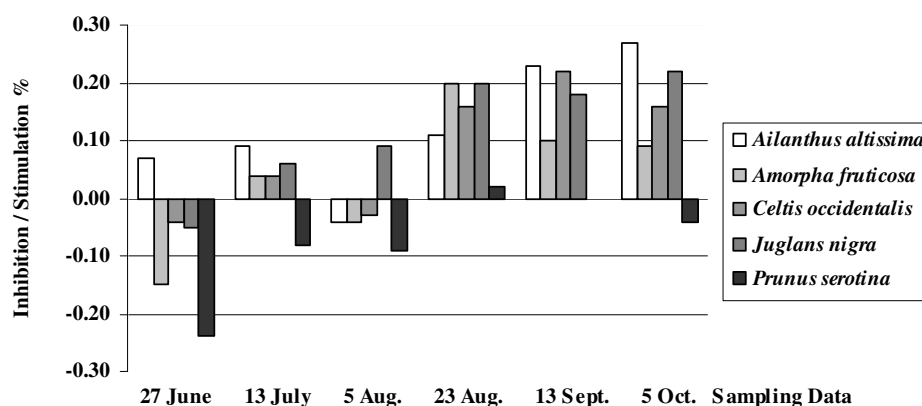


Figure 2. Effects of dried plant materials of 5- invasive woody plant species on height of *Quercus robur* L. over control

The explanation of little allelopathic effects under the field conditions can be the transformation of allelochemicals by organic and anorganic compounds of soil, adsorption by colloids and dilution by the precipitation (5). As Inderjit and Weston (25) reported that the release of chemicals does not necessarily guarantee an allelopathic interaction unless

chemicals, or their degraded products, accumulate in the environment in bioactive concentrations for enough time to bring about a growth response (25). *Quercus robur* L. was chosen as test species because of its importance in forestry and nature conservation, but it is difficult to study due to its slow early growth. Robakowski and Bielinis (53) experienced similar phenomenon studying potted seedlings of *Quercus petraea* L. adding fresh *Prunus serotina* Ehrh. leaves to the substrate to enhance allelopathic effects. The results of their study did not show any inhibitory effect on oak growth. On the contrary, the presence of black cherry seedlings stimulated the oak height.

Invasive alien species cause considerable environmental, economical and human health harm worldwide; therefore studies on every factor which helps their establish, naturalization and further spread are a high priority. Our results could contribute to a better understanding of complex processes between invaded ecosystems and invasive alien species, and serving a starting point for further studies.

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REFERENCES

1. An, M., Pratley, J.E. and Haig, T. (1997). Phytotoxicity of *Vulpia* residues. 1. Investigation of aqueous extracts. *Journal of Chemical Ecology* **23**: 1979-1995.
2. Balogh, L. Dancza, I. and Király, G. (2004). Current list of neophytes in Hungary and their classification according to their success. In: *Biológiai Inváziók Magyarországon. Őzönművények*. (Eds. B. Mihály and Z. Botta-Dukát) pp. 61-92. TermészetBÚVAR Alapítvány Kiadó, Budapest, Hungary. (Hungarian).
3. Béres, I., Kazinczi, G. and Lukác, D. (2001). Allelopathic effects of some weeds in Hungary. In: *6. Tiszántúli Növényvédelmi Fórum*, Debrecen, 6-8 November, 2001, pp. 353-361. (Hungarian).
4. Botta-Dukát, Z. and Balogh, L. (Eds.) (2008). *The Most Important Invasive Plants in Hungary*. Hungarian Academy of Sciences, Institute of Ecology and Botany, Vácrátót, 255 pp.
5. Brückner, D.J. and Szabó, L.Gy. (2001). New approaches to allelopathy. *Kitaibelia* **4**: 93-106. (Hungarian)
6. Callaway, R.M. and Aschehoug, E.T. (2000). Invasive plants versus their new and old neighbours: a mechanism for exotic invasion. *Science* **290**: 521-523.
7. Csiszár, Á. (2009). Allelopathic effects of invasive woody plants species in Hungary. *Acta Silvatica et Lignaria Hungarica* **5**: 9-17.
8. Csontos, P. (1997). Allelopathy in Hungary: A review of literature. *Természetvédelmi Közlemények* **5-6**: 27-40. (Hungarian)
9. Daglish, C. (1950). The determination and occurrence of hydrojuglone glucoside in walnut. *Biochemical Journal* **47**: 45-462.
10. Dilday, R.H., Lin, J. and Yan, W. (1994). Identification of allelopathy in the USDA-ARS rice germplasm collection. *Australian Journal of Experimental Agriculture* **34**: 907-910.
11. Duke, S.O., Dayan, F.E., Hernandez, A., Duke, M.V. and Abbas, H.K. (1997). Natural products as leads for new herbicide mode of action. In: *Brighton Crop Protection Conference - Weeds*. pp. 578-586. Brighton, UK.
12. Elakovich, S.D. and Wooten, J.W. (1995). Allelopathic woody plants I. *Abies alba* through *Lyonia lucida*. *Allelopathy Journal* **2**: 117-146.

13. Elakovich, S.D. and Wooten, J.W. (1996). Allelopathic woody plants II. *Mabea* through *Zelkova*. *Allelopathy Journal* **3**: 9-32.
14. Ercisli, S., Esitken, A., Turkkal, C. and Orhan, E. (2005). The allelopathic effects of juglone and walnut leaf extracts on yield, growth, chemical and PNE compositions of strawberry cv. Fern. *Plant, Soil and Environment* **51**: 283-287.
15. Friebe, A., Schulz, M., Kück, P. and Schnabl, H. (1995). Phytotoxins from shoot extracts and root exudates of *Agropyron repens* seedlings. *Phytochemistry* **38**: 1157-1159.
16. Gentle, C.B. and Duggin, J.A. (1997). Allelopathy as a competitive strategy in persistent thickets of *Lantana camara* L. in three Australian forest communities. *Plant Ecology* **132**: 85-95.
17. Gonzales, L., Souto, X.J. and Reigosa, M.J. (1997). Weed control by *Capsicum annum*. *Allelopathy Journal* **4**: 101-110.
18. Guo, Z. L., Cai C. F., Zheng, Z. J. (2010). Allelopathic Effect of Leaf Water Extracts from *Amorpha fruticosa* on Germination and Seedling Growth of Soybean and Fababean. *Journal of Huazhong Agricultural University* **4**: 452-456
19. Heisey, R.M. (1996). Identification of an allelopathic compound from *Ailanthus altissima* and characterization of its herbicidal activity. *Journal of Botany* **83**: 192-200.
20. Heisey, R.M. (1997). Allelopathy and the Secret Life of *Ailanthus altissima*. *Arnoldia* **57**: 28-36.
21. Hejl, A.M., Einhellig, F.A., and Rasmussen J. (1993). Effects of juglone on growth, photosynthesis and respiration. *Journal of Chemical Ecology* **19**: 559-568.
22. Hierro, J.L. and Callaway, R.M. (2003). Allelopathy and exotic plant invasion. *Plant and Soil* **256**: 29-39.
23. Horsley, S.B. (1979). Decomposition of the cyanogenic glycoside of *Prunus serotina*: a possible allelopathic mechanism. *Botany Society of America Miscellaneous Publication* **157**: 41
24. Inderjit and Dakshini, K.M.M. (1998). Allelopathic interference of chickweed, *Stellaria media* with seedling growth of wheat (*Triticum aestivum*). *Canadian Journal of Botany* **76**: 1317-1321.
25. Inderjit and Weston, L.A. (2000). Are laboratory bioassays for allelopathy suitable for prediction of field responses? *Journal of Chemical Ecology* **26**: 2111-2118.
26. InStat (1997). GraphPad InStat Demo, Version 3.00 for Win 95/NT. GraphPad Software Incl., San Diego.
27. Jose, S. and Gillespie, A.R. (1998). Allelopathy in black walnut (*Juglans regia* L.) alley cropping: II. Effects of juglone on hydroponically grown corn (*Zea mays* L.) and soybean (*Glycine max* L. Merr.) growth and physiology. *Plant and Soil* **203**: 199-205.
28. Kazinczi, G., Béres, I., Horváth, J. and Takács, A.P. (2005). Allelopathic weeds. In: *Növényvédelmi Tudományos Napok*, p. 73. Budapest. (Hungarian).
29. Kazinczi, G., Béres, I., Hunyadi, K. and Mikulás, J. (1991). Study of allelopathic effect and competitive ability of *Abutilon theophrasti*. *Növénytermelés* **40**: 321-331. (Hungarian)
30. Keeley, J.E. (1988). Allelopathy. *Ecology* **69**: 293-294.
31. Kocacaliskan, I. and Terzi, I. (2001). Allelopathic effects of walnut leaf extracts and juglone on seed germination and seedling growth. *Journal of Horticultural Science and Biotechnology* **76**: 436-440.
32. Kruse, M., Strandberg, M. and Strandberg, B. (2000). *Ecological Effects of Allelopathic Plants – A Review*, National Environmental Research Institute, NERI Technical Report No. **315**, Silkeborg, Denmark, 67 pp.
33. Lodhi, M.A.K. (1978) Allelopathic effects of decaying litter of dominant trees and their associated soil in a lowland forest community. *American Journal of Botany* **65**: 340-344.
34. Macias, F.A., Castellano, D., Oliva, R.M., Cross, P. and Torres, A. (1997). Potential use of allelopathic agents as natural agrochemicals. In: *Crop Protection Conference*, Volume **1**: pp. 33-38. Brighton.
35. Macias, F.A. (1995). Allelopathy in the search for natural herbicides models. In: *Allelopathy Organisms, Processes and Applications* (Eds. Inderjit, K.M.M. Dakshini and F.A. Einhellig) *American Chemical Society* **60**: 310-329.
36. Macias, F.A., Molinillo, J.M.G., Torres, A., Varela, R.M. and Castellano, D. (1997). Bioactive flavonoids from *Helianthus annuus* cultivars. *Phytochemistry* **45**: 683-687.
37. Macias, F.A., Simonet, A.M., Galindo, J.C.G., Pacheco, P.C. and Sanchez, J. (1998). A Bioactive polar triterpenoids from *Melilotus messanensi*. *Phytochemistry* **49**: 709-717.
38. Miller, D.A. (1996). Allelopathy in forage crop systems. *Agronomy Journal* **88**: 854-859.
39. Molisch, H. (1937). *Der Einfluß einer Pflanze auf die Andere. Allelopathie*. Gustav Fischer Verlag, Jena, 106 pp.
40. Moyer, J.R. and Huang, H.C. (1997). Effect of aqueous extracts of crop residues on germination and seedling growth of ten weed species. *Botanical Bulletin of Academia Sinica* **38**: 131-139.

41. Nandal, D.P.S., Bisla, S.S., Narwal, S. S. and Kaushik, J.C. (1994). Allelopathic interactions in agroforestry systems. In: *Allelopathy in Agriculture and Forestry* (Eds. S.S. Narwal and P. Tauro) pp. 93-130. Scientific Publishers, Jodhpur, India.
42. Narwal, S.S., Sarmah, M.K. and Tamak, J.C. (1996). Allelopathic strategies for weed management in the rice-wheat rotation in northwestern India. In: *Allelopathy in Rice* (Ed. M. Olofsdotter), Proceedings of the Workshop on Allelopathy in Rice, pp. 117-131. International Rice Research Institute, Manila, IRRI Press, 25-27 November, 1996.
43. Olofsdotter, M. and Navarez, D. (1996). Allelopathic rice for *Echinochloa crus-galli* control. *Second International Weed Control Congress*, pp. 1175-1180. Copenhagen.
44. Olofsdotter, M., Navarez, D., Rebulana, M., and Streibig, J.C. (1999). Weed-suppressing rice cultivars - Does allelopathy play a role? *Weed Research* **39**: 441-454.
45. Parepa, M., Schaffner, U., Bossdorf, O. (2011). Mechanism of interference between invasive knotweeds and their native competitors. In: *11th International Conference on the Ecology and Management of Alien Plant Invasions*. p. 45. Szombathely, Hungary, 30 August - 3 September.
46. Prataiviera, A.G., Kuniyuki, A.H. and Ryogo, K. (1983). Growth inhibitors in xylem exudates of Persian walnut (*Juglans regia* L.) and their possible role in graft failure. *Journal of the American Society of Horticultural Science* **108**: 1043-1050.
47. Putnam, A.R. and Weston, L.A. (1986). Adverse impacts of allelopathy in agricultural systems. In: *The Science of Allelopathy* (Eds. A.R. Putnam and C.S. Tang) pp. 43-65. John Wiley & Sons, New York.
48. Rice, E.L. (1984): *Allelopathy*. Second Edition. Academic Press, Orlando, 422 pp.
49. Richardson, D.M., Pyšek, P., Rejmánek, M., Barbour, M.G., Panetta, F.D. and West, C.J. (2000). Naturalization and invasion of alien plants: Concepts and definitions. *Diversity and Distributions* **6**: 93-107.
50. Ridenour, W.M. and Callaway, R.M. (2001). The relative importance of allelopathy in interference: The effects of an invasive weed on a native bunchgrass. *Oecologia* **126**: 444-450.
51. Rietveld, W.J. (1983). Allelopathic effects of juglone on germination and growth of several herbaceous and woody species. *Journal of Chemical Ecology* **9**: 295-308.
52. Rizvi, S.J.H. and Rizvi, V. (1992). Exploitation of allelochemicals in improving crop productivity. In: *Allelopathy: Basic and applied aspects*. (Eds. S.J.H. Rizvi. and V. Rizvi) pp. 443-473. Chapman and Hall, London.
53. Robakowski, P. and Bielini, E. (2011). Competition between Sessile oak (*Quercus petraea*) and Black cherry (*Padus serotina*): Dynamics of seedlings growth. *Polish Journal of Ecology* **59**: 297-306.
54. Segura-Aguilar, J., Hakman, I. and Rydstrom J. (1992). The effect of 5-OH-1,4 naphthoquinone on Norway spruce seed during germination. *Plant Physiology* **100**: 1955-1961.
55. Shibu, J. and Gillespie, A.R. (1998). Allelopathy in black walnut (*Juglans nigra* L.) alley cropping I. Spatio-temporal variation in soil juglone in a black walnut-corn (*Zea mays* L.) alley cropping system in the midwestern USA. *Plant and Soil* **203**: 191-197.
56. Shibu, J. and Gillespie, A.R. (1998). Allelopathy in black walnut (*Juglans nigra* L.) alley cropping II. Effects of juglone on hydroponically grown corn (*Zea mays* L.) and soybean (*Glycine max* L. Merr.) growth and physiology. *Plant and Soil* **203**: 199-205.
57. Szabó, L.Gy. (1997). *Allelopathy - Phytochemical potential -Life strategy*. JPTE, Pécs, 188 pp.
58. Szabó, L.Gy. (1999). Juglone index - a possibility for expressing allelopathic potential of plant taxa with various life strategies. *Acta Botanica Hungarica* **42**: 295-305.
59. Terzi, I. (2008). Allelopathic effects of Juglone and decomposed walnut leaf juice on muskmelon and cucumber seed germination and seedling growth. *African Journal of Biotechnology* **7**: 1870-1874.
60. Vrchotová, N., Šerá, B. and Krejčová, J. (2011). Allelopathic activity of extracts from *Impatiens* species. *Plant, Soil and Environment* **57**: 57-60.
61. Wardle, D.A., Nilson, M-C., Gallet, C. and Zackrisson, O. (1998). An ecosystem-level perspective of allelopathy. *Biological Reviews* **73**: 301-309.
62. Weston, L.A. (1996). Utilization of allelopathy for weed management in agroecosystems. *Agronomy Journal* **88**: 860-866.
63. Willis R. (Ed.) (1998). Allelopathy – Defined? International Allelopathy Society, *Second IAS Newsletter* **2** (1).
64. Wu, H., Pratley, J., Lemerle, D. and Haig. T. (1999). Crop cultivars with allelopathic capability. *Weed Research* **39** (3): 171-180.