UDC 504.53.052:504.73.05(045)

Olga Shtyka[1]
Tetyana Bilyk[2]
Olena Andrushchenko[3]

ALLELOPATHICAL ACTIVITY ASSESSMENT AS THE IMPORTANT STAGE OF PHYTOREMEDIATION TECHNOLOGY DEVELOPMENT

[1, 2]National Aviation University
1, Kosmonavta Komarova avenue, Kyiv, 03680, Ukraine
[3]M. M. Gryshko National Botanic Garden
1, Timiryazevska Str, Kyiv, 01014, Ukraine
E-mails: [1]olga.shtyka@gmail.com, [2]larus_2010@ukr.net, [3]novaflora@ukr.net

Abstract. *Phytoremediation is acknowledged as the perspective technology of soil decontamination and recovery. Nevertheless, there are certain factors that are supposed to influence this process, decreasing its effectiveness. The introduction of phytoremediation plants as the non-indigenous species into a phytocenosis of contaminated area may initiate the activation of an allelopathic activity of the present species. Allelopathic activity is commonly defined as a process of secretion of the secondary metabolites in a form of volatile compounds, exudates that inhibit development of other plants. Thus, this research work focuses on the assessment of an allelopathic activity of the indigenous species and its influence on selected phytoremediation plants. Bioassay and germination test have been conducted to measure the effects of water-soluble extracts of Amaranthus retroflexus* L., *Cirsium arvense* L., *Barbarea vulgaris* R. Br. *and Artemisia absinthium* L. *on the introduced species used in phytoremediation*.

Keywords: allelopathy; bioassay; germination test; introduced species; phytoremediation; water–soluble extract.

1. Introduction

An ecosystem as a community of living organisms is specified by both internal and external mutual interactions. The competition between species is considered to be one form of such interconnections [1]. A species may enter into competition with others for a habitat, resources e.g. water, nutrients, light, etc. [1, 2].

In the scientific literature, the term "allelopathic interaction" is used to describe the chemical competition between living organisms in an ecosystem which reflects the suppressing of germination process, the inhibiting of growth, development, and the reproduction rate of the adjacent organisms [3, 4]. The mentioned physiological phenomenon is based on releasing of inhibitory substances by a plant that causes depression of other species sharing the same habitat. These specific substances have been known as allelochemicals and are represented by the secondary metabolites consisting of organic compounds, e.g. flavonoids, terpenoids, alkaloids, phenolic compounds, benzoxazolinone (BOA) and many others [5, 6, 7, 8, 9, 10, 11].

Thus, allelopathic species express the ability to cause the phytotoxical stress on neighboring plants by means of allelochemicals secreting from plumule or radical systems mainly in a form of volatile compounds, exudates or due to their residues decaying in a soil layer [7, 10, 12].

The entire process starting from the allelochemicals production till their release into the environment and subsequently, mechanisms of influences are found as slightly investigated. Modes of allelochemicals action were described in the asset of scientific publication [6, 9, 10, 13, 14]. From the beginning, allelochemicals may affect the membrane that activates the subsequent modifications in the biochemical and physiological processes inside a plant-target. The initiated changes are connected mostly with damaging of the important molecular targets, e.g. cells integrity, photosynthesis and biosynthesis processes, production of enzymes, replication, respiration and metabolism etc. [6, 10, 13, 14].

Manifestation of the allelopathic activity can be regarded as a mechanism of organisms defense against not only competitors, but also herbivores, predators and parasites. Moreover allelopathic interactions play the important role in control of biodiversity within an ecosystem via regulation of the species distribution, abundance in communities and limitation of population of the associated species [3, 15, 16].

In the phytoremediation technology, allelopathic interaction is considered to be the influential aspect that may define the efficiency and success of plants introduction in a phytocenosis of the investigated territory and consequently, the entire process of recovery.

2. Analysis of research and publication

For the first time, allelopathic interactions were indicated and described as a secretion of phytotoxic compounds by plants, algae and microorganisms (e.g. actinomycetes, fungi etc.) in works of Hans Molisch in 1937 [17]. Further researches led to the following directions: modes of allelopathic compounds influence on plants development; identification of allelochemicals released by plants; modeling of allelopathic compounds influence on the biochemical and physiological processes of an organism-target; allelopathic interactions on ecosystem levels; allelopathy using in the biotechnology, agriculture and other industrial sectors.

The process of allelopathic compounds discharging into the environment, then the chemistry and interactions, and finally their characteristics and biological functions were analyzed in a great deal of scientific publications [6, 7, 9, 11]. The majority of the allelopathic chemicals is represented by hydrophilic compounds, among which are: phenolics, terpenoids, alkaloids, flavonoids and glycosides etc. [6, 7, 8, 10, 14, 15].

The mechanism of allelochemicals releasing by the exudation of radicals, the factors affecting this process and the exudates impact on nutrients and soil microflora were firstly reviewed in the work of Rovira and then in the further publications of Inderjit, Chou, Blum [12, 15, 18, 19]. Chou described allelopathic chemicals and educed more than 20 phenolic compounds as the radical exudates and decomposed crop residues [15]. The significant role of allelopathy as chemical interactions between species in a process of adaptation and communities' organization was also investigated in a set of scientific publications [15, 16].

With most of the scientists assuming his position, Einhellig proposed that in consequence of the diversity of allelopathic compounds, their manifestation of phytotoxicity may be caused by a common mechanism starting with cellular disruption rather than the specific modes of action [9]. The several possible modes of influence for allelochemicals were declared using the example of ferulic acid [10], phenolic compounds [9] terpenoids [8], alkaloids [6], and BOA [11, 14]. Thus, the subsequent actions after penetration of allelochemicals as phytotoxic compounds into a plant-target are supposed to be different. In the scientific literature, frequently observed modifications are followings: changing of the membrane permeability; affecting of mitosis, elongation and creation of ultra structures of cells; suppressing of photosynthesis, protein biosynthesis, metabolism of organic acids and lipids, minerals and water uptake; inhibiting of enzymes activity and respiration process [4, 6, 9, 10]. The influence of allelochemicals (i.e. alkaloids) on DNA and RNA synthesis was established in the work of Wink and Latz-Brüning [6].

In reason of their influence on the biological and environment availability, on the chemical stability and toxicity of allelochemicals, the external factors may define the effectiveness of an allelochemical activity. The main factors are the followings: composition and structure of the soil, temperature, photoperiod, and interactions with other resealed allelopathic compounds. It is presumed that the appearing of a lack of nutrients and a water limitation may also influence on the allelochemicals production and activity. In some cases, the activation and intensification of allelochemicals production by plant were observed; in others it was found an augmentation of the toxicity of these compounds [20].

Thus, the majority of the earlier researches in the sphere of allelopathy focused on the elucidation of allelopathic mechanisms. At present, there is a continuous scientific interest for the allelopathic effects application to promote sustainable agriculture and forestry, and to increase the efficiency of technologies based on plant species introduction. In the mentioned spheres, the research connects mainly with examination of interactions and effects in systems: weed plant–crop plant; crop plant–weed plant, and crop plant–crop plant [20, 21, 22, 23, 24].

Phytoremediation is a technology based on plants introduction into the contaminated environment, consequently the non–indigenous species might interact with the native plants. Mutual influences may reveal manifestations of the allopathic activity of both species. These influences can be noticed by the direct secretion of allelochemicals (in the case of "in situ"), or by the ongoing presence of allelochemicals in the excavated soil in a form of products of plants residues decay (in the case of "in vitro"). Thus, investigation of allelopathic activity of weed species, being the quite widespread on the industrial and urbanized contaminate territories, has become actual environmental issues.

From agricultural point of view, the allelopathic activity of weeds and its potentiality is under continuous scientists' attention, and the results of their investigation are represented in a set of publications [20, 21, 23, 24, 25].

Acroptilon repens (L.) DC. was amongd the first investigated weed species. This plant was defined to cause inhibition of other species (i.e. *Panicum miliaceum* L., Medicago *sativa* L., and *Echinochloa crus-galli* (L.) P.Beauv.) sharing the same habitat [26]. The allelopathic potential of *Pedicularis kansuensis* was also examined. The research were conducted to evaluate this species influence on seed germination and seedling growth of two native species of grasses *Poa pratensis* and *Elymus nutans* Griseb. [24].

The allelopathic effect of such weeds, as: *Melilotus indicus* (L.) All., *Cynodon dactylon* (L.) Pers., *Chenopodium album* L., *Convolvulus arvensis* L., *Coronopus didymus* (L.) Sm., *Lathyrus aphaca* L., *Vicia hirsuta* (L.) Gray, *Rumex acetosella* L. etc., on *Phalaris minor* Retz. was investigated in work of Om and his co-authors. Such species as *C. album, M. indicus, C. arvensis* were considered as able to manifest strong inhibiting effects causing suppression of 100 % germination over control [21].

The allelochemicals which were extracted from leaves of *Lantana camara* Linn. and their effects on *Bidens pilosa* Linn. (i.e. chlorophyll and protein contents, and amount of carbohydrate) were examined in the publication of Sisodia and Siddiqui [25].

The allelopathic activity of *Croton bonplandianum* Baill. and its influence on seed germination and rate of seedlings development of both weed plants (*Vicia sativa* L., *Melilotus albus* Medik., and *Medicago hispida* Gaertn) and crop plants (i.e. *Brassica rapa* L., *Brassica oleracea var. botrytis* L. and *Triticum aestivum* L.) was also reviewed [27].

Such ruderal weed species, as: *Amaranthus retroflexus* L., *Cirsium arvense* (L.) Scop., *Barbarea vulgaris* W.T.Aiton and *Artemisia absinthium* L. which are considered as quite widespread in soils of urbanized territory and were investigated in present research work.

3. The Purpose of the work

The purpose of the present research work was to make an assessment of the ability to release inhibitory substances of the widespread species growing on the investigated contaminated territory, and consequently, to analyze a process of phytoremediation plants growth depression.

The applied approach allowed us to distinguish allelopathic effects from others, mainly abiotic factors, e.g. acidity level of the soil, mineral composition of the medium, humidity etc., which may also influence on plants growth and development rate.

4. Materials and methods of the investigation

The objects of the investigation were such species: *Amaranthus retroflexus L., Cirsium arvense L., Barbarea vulgaris R. Br.* and *Artemisia absinthium L.* (i.e. indigenous species of investigated territory). The selected potential phytoremediation plants were *Amaranthus caudatus L.* and *Amaranthus paniculatus L.*

The current research work provides an estimation of an allelopathic activity of the water- soluble extracts exhausted from the mentioned indigenous species and its influence on the investigated phytoremediation plants. The influence of extracts on biotester was investigated in our earlier publications. In this investigation, *Lactuca sativa L.* was used as a target species and as an additional control sample which purpose was to define correlation between influences on phytoremediation plants and biotester, and to compare the obtained results.

Bioassay and seed germination test are considered to be the appropriate methods of analysis due to their efficiency, their high responsivity to affect various chemicals, and their short-time experiments.

The first stage consisted in preparing the water-soluble extracts from indigenous species. The plants with radicals were selected in a period of florescence on the territory of the standing airport. Initially, the selected material was dried, then reduced to fine particles with further pounding. The extracts were prepared by taking 20 g of crushed plants material and adding 100 ml of distilled water. The extraction went on during 24 hours.

The second stage of the investigation foresaw bioassay using seeds of phytoremediation plants and *L. sativa* (control sample). The process of seeds germination is known as the most vulnerable phase of plant development therefore minimal resistance to such negative factors as allelochemicals action may be observed.

Bioassay has been performed according to the accepted methodology on filter paper in the Petri's dishes [28]. The prepared extracts in amount of 5 ml served as a medium. The seeds of biotester *L. sativa 'Kucheriawy'*, *A. caudatus 'Karmin'* and *'Helios'*, *A. paniculatus 'Zhaivir'* were used. Four replications (25 seeds in one) were made for each sample and the concentration of extracts remained the same.

The experiments have been carried out under the standard conditions with a temperature of 22±1^{0}C without penetration of light. The incubation period was equal to 120 hours. Potable water served as a control medium.

A screening-test was fulfilled immediately after incubation and gave the ability to define the reaction of plants on allelochemicals presented in the investigated extracts. The screening-test provided measuring of the following parameters: the germination percentage, the plumules length and the radicals length. The morphological changes of the seedlings structure grown in the prepared media may confirm suppressing and depressing affects.

The germination percentage is defined in accordance to the expression:

$$G_{\%} = \frac{\sum G}{N} \times 100,$$

where $G_{\%}$ is the germination percentage; G is the number of the germinated seeds; N is the number of seeds.

5. Analysis of the results and discussion

The experimental data concerning the influence of the water-soluble extracts prepared from the indigenous species on *A. caudatus*, *A. paniculatus*, and biotester *L. sativa* were represented in Tables 1-3.

The analysis of the germination test results showed that *B. vulgaris.* had a significant effect on the seedlings development. A strong inhibition of the seeds germination was observed for *A. caudatus* (amount of the developed seedlings decreased by 44 % comparing with control), and *L. sativa* possessed 60 % of germinated seedlings. Among all investigated species, *A. paniculatus* was found to have the highest index of germination rate and constituted 65 % of developed seedlings (see Table 1).

According to obtained results, the water–soluble extracts of *A. absinthium* and *C. arvense* affected more *A. caudatus 'Karmin'* and *L. sativa*. In the case of *A. absinthium*, the germination suppression of 44 % of the plants seeds was noticed. *C. arvense* caused a development rate reduction of 54 %. *A. paniculatus* and *A. caudatus 'Helios'* were uncovered as less suffered species.

Table 1. Germination rate of the investigated species

Type of plant	Amount of germinated seeds, [amount/%]			
	A. caudatus 'Karmin'	*A. caudatus 'Helios'*	*A. paniculatus 'Zhaivir'*	*L. sativa*
A. retroflexus	20/80	22/88	22/88	20/80
C. arvense	16/64	15/72	19/76	16/64
B. vulgaris	14/56	14/56	16/64	15/60
A. absinthium	14/56	16/64	18/72	14/56
Control	24/96	24/96	25/100	25/100

The extract of *A. absinthium* suppressed seeds germination by 28 % and 36 % correspondingly, while *C. arvense* inhibited 24 % of *A. caudatus 'Helios'* seeds and 28 % of *A. paniculatus*.

A. retroflexus caused relatively slight suppressing of seeds germination: 12 % of *A. paniculatus* and *A. caudatus 'Helios'*, and 20 % of *A. caudatus 'Karmin'* and *L. sativa* were appreciated as undeveloped (see Table 1).

The reduction of radicals and plumules length may be also considered to be a result of the inhibition activity of allelochemicals present in the prepared extracts. The results of radicals measuring were represented in Table 2.

Table 2. Inhibition influence of extracts on the radicals length of phytoremediation plants

Type of plant	Average value of the radicals length, [cm]			
	A. caudatus 'Karmin'	*A. caudatus 'Helios'*	*A. paniculatus 'Zhaivir'*	*L. sativa*
A. retroflexus	3.8 ±0.01	3.6 ±0.01	4.4 ±0.02	4.8 ±0.01
C. arvense	3.3 ±0.02	3.2 ±0.02	4.0 ±0.03	3.3 ± 0.03
B. vulgaris	2.5 ±0.03	2.5 ±0.04	3.6 ±0.04	3.9 ±0.04
A. absinthium	2.3 ±0.03	2.3 ±0.02	2.7 ±0.04	3.1 ±0.01
Control	4.7 ±0.03	4.5 ±0.02	5.1 ±0.01	5.9 ±0.02

The extract of *A. absinthium* caused significant reduction of radicals length. The seedlings of *A. caudatus 'Karmin'* presented the highest decreasing of the radicals length – 52 % (2.3±0.03 cm) in comparison with control sample length (4.7±0.03 cm).

For other species, the value of radicals inhibition was in a range of 46–50% (radicals length of *A. caudatus 'Helios'* was equal to 2.3±0.02 cm, *Amaranthus paniculatus* – 2.7±0.04 cm, and *L. sativa* – 3.1±0.01 cm).

The extract of *B. vulgaris* decreased the length of radical by 47 % for *A. caudatus* 'Karmin', having a length of 2.5±0.03 cm. The radical length of *A. caudatus 'Helios'* was reduced by 45%, being 2 cm shorter than control sample (4.5±0.02 cm). The radicals suppression rate of *A. paniculatus* and *L. sativa* was respectively equal to 30 % (1.5 cm less comparing with control) and 35 % (2 cm less).

The most vulnerable species to the action of *C. arvense* was *L. sativa*, having a reduction of radical length of 41 % (3.3±0.03 cm, control sample length was 5.9±0.02 cm). *C. arvense* caused a depression of radicals development of 39 % for *A. caudatus* 'Karmin' (3.3±0.02 cm, control sample – 4.7±0.03 cm), and 29 % for *A. caudatus 'Helios'* (3.2±0.02 cm, control sample – 4.5±0.02 cm). *A. paniculatus* was considered as the species with the highest influence-restriction to the of *C. arvense* extract (reduced by 22 %).

In the case of *A. retroflexus*, the suppression of radicals length was the lowest, and the values were in a range of 14–20 % (see Table 2).

The results of plumules length measuring were represented in Table 3.

Table 3. Inhibition influence of extracts on the plumules length of phytoremediation plants

Type of plant	Average value of the plumule length, [cm]			
	A. caudatus 'Karmin'	*A. audatus 'Helios'*	*A. paniculatus 'Zhaivir'*	*L. sativa*
A. retroflexus	3.4 ±0.01	3.3 ±0.02	3.6 ±0.02	2.8 ±0.01
C. arvense	2.3 ±0.05	2.4 ±0.04	3.1 ±0.03	2.8 ±0.01
B. vulgaris	2.1 ±0.03	2.5 ±0.02	2.3 ±0.02	1.9 ±0.03
A. absinthium	3.3 ±0.01	3.2 ±0.03	3.5 ±0.01	2.4 ±0.02
Control	4.1 ±0.02	4.0 ±0.01	4.2 ±0.01	3.5 ±0.02

A. retroflexus and *A. absinthium* had relatively slight influence on the development of all investigated species plumules. It manifested a reduction of the plumules length corresponding of 15-18 % for *A. retroflexus* extract, and 18-22 % for *A. absinthium*. The lowest level of influence-resistance was shown by biotester *L. sativa, A. retroflexus* caused decreasing of plumules length of 21 %, and *A. absinthium* reduced upper part of plants by 30 % over their control samples.

The most vulnerable species to the action of *C. arvense* extract were both cultivars of *A. caudatus.* The radicals length of *A. caudatus 'Karmin' decreased* by 46 %, constituting 2.3±0.05 cm, while control sample had a length of 4.1±0.02 cm. The average plumules length of *A. caudatus* 'Karmin' grown in extract was equal to 3.1±0.03 cm, while plumules in control replication reached 4.0±0.01 cm. Thus, *C. arvense* caused a reduction of upper part of this species of 40 %.

The inhibition effect of *B. vulgaris* was observed as the decreasing of *A. caudatus* 'Karmin' plumules length of 49 % (the average value of length is 2.1±0.03 cm), and *L. sativa* of 46 % (i.e. the plumules length was 1.9±0.03 cm). The extract of *B. vulgaris* was specified as being able to suppress development of upper part of *A. caudatus 'Helios'* as well as *A. paniculatus*. It manifested reducing of plumules length of both species by 39% (in average length was 1.5-1.9 cm less than in control replications).

In several scientific publications, the reduction of radical and plumule length was referred as the result of secondary effects [8] The morphological defects of seedlings structure, especially their radicals, are considered to be the primary symptoms of affects caused by inhibiting compounds [8].

The results of the screening-test concerning morphological changes are represented in Figures 1-3. According to the obtained data, the extract of *A. retroflexus* caused non-significant influence on the investigated species. It manifested radicals endings withering for 4 % of cultivars of *A. caudatus*. In the case of *A. paniculatus* and *L. sativa*, no morphological affection was observed.

The investigated extract of *C. arvense* caused suppression of both radicals and plumules. On the one hand, the radicals withering was found to be a specific feature for 8 % *A. caudatus 'Helios'*, and for 4 % of *A. paniculatus*. On the other hand, the radicals twisting was observed for 4% *A. caudatus* 'Karmin', and for 8 % of *L. sativa*. The negative influence of *C. arvense* extract also demonstrated plumules withering that was typical for all species. *A. caudatus* was defined as the most vulnerable (see fig. 1).

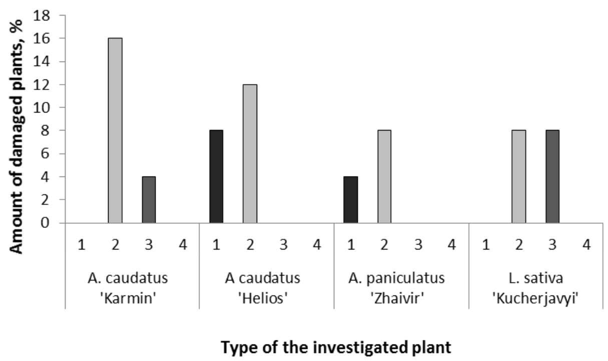

Fig. 1. Morphological changes of seedlings structure grown in the water extract of *C. arvense*:
1 – withering of radicals;
2 – withering of plumules;
3 – twisting of radicals;
4 – others

The extract of *B. vulgaris* influenced mainly on plumules development by suppressing it and causing the seedlings plumules withering. This phenomenon appeared for 16 % of *A. caudatus* 'Karmin', *A. paniculatus 'Zhaivir'*, and *L. sativa.* The radicals twisting was observed for 12 % of *A. caudatus* 'Karmin', for 8 % of *A. caudatus 'Helios'*, and for 4 % of *L. sativa*, while the roots withering for 4 % of *A. caudatus 'Helios'* and for 8 % of *L. sativa* (see fig. 2).

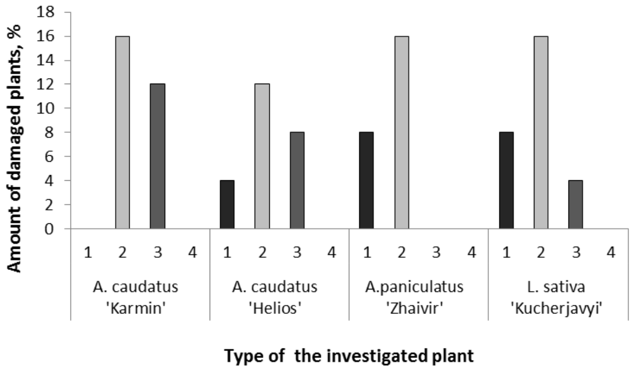

Fig. 2. Morphological changes of seedlings structure grown in the water extract of *B. vulgaris*:
1 – withering of radicals;
2 – withering of plumules;
3 – twisting of radicals;
4 – others

The most vulnerable species were *A. caudatus* 'Karmin' and *L. sativa*, and the general amount of damaged plants in each investigated replication was up to 28 %.

The extract of *A. absinthium* caused on the investigated species a depression of radicals system. The plants being the less resistant to extract action were from both cultivars of *A. caudatus* (24 % of damaged seedlings), while *A. paniculatus* was defined as the less vulnerable (down to 16 %).

The seedlings quantity with twisted radicals in each investigated case was equal to 12% (see fig. 3).

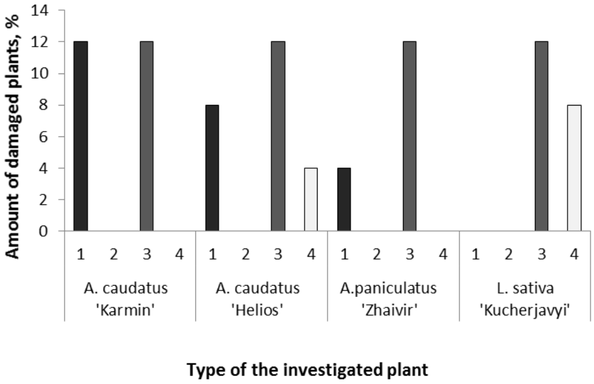

Fig. 3. Morphological changes of seedlings structure grown in the water extract of *A. absinthium*:
1 – withering of radicals;
2 – withering of plumules;
3 – twisting of radicals;
4 – others

The radicals withering was defined as a specific character for 12 % of *A. caudatus* 'Karmin', for 8 % of *A. caudatus 'Helios'*, and for 4% of *A. paniculatus.* While the seedlings of *L. sativa* (8 %) and *A. caudatus 'Helios'* (4 %) were found with undeveloped plumules (see Fig. 3).

The amount of damaged seedlings in each observed case of a morphological modification did not exceed 16 % of the initial amount of seeds. In the control samples, morphological changes were not observed.

6. Conclusions

To develop the efficient and successful strategy of such decontamination technology as phytoremediation, it is crucial to understand a mechanism by which the indigenous species may affect the introduced phytoremediation plants and to define a possible rate of plants suppression and inhibition.

In particular, our research has been focused on knowing the allelopathic effects of indigenous species (i.e. *C. arvense, A. absinthium, A. retroflexus,* and *B. vulgaris*) over introduced phytoremediation plants (i.e. *A. paniculatus* and *A. caudatus*), and biotester *L. sativa*.

An analysis of the obtained experimental data showed that the extract of *C. arvense* and *B. vulgaris* inhibited the most growth of biotester *L. sativa* and investigated phytoremediation plants. In some cases, the plumules length was decreased by 49 %

(*A. caudatus* 'Karmin'), comparing with length of control sample.

On the other hand, the extracts of *A. absinthium* and *B. vulgaris* species may cause also significant suppression of the radicalsystem development. *A. caudatus* 'Karmin' had the maximal reduction of radicals length among species which was equal to 52 % in case of *A. absinthium* extract of, and 47 % in the case of *B. vulgaris*.

A. retroflexus was considered as manifesting the slight influence on species development, and suppression rate was in range of 15-21 %.

According to results of the germination test, in general *A. paniculatus* was defined as the less vulnerable species to negative influence of all investigated extracts. But in the case of *B. vulgaris*, the depression rate of this phytoremediation plant was the highest and was equal to 36 %, the lowest amount of undeveloped seeds was observed in the case of *A. retroflexus* (12 %).

Analyzing the obtained results, it is possible to assume *B. vulgaris* and *A. absinthium* had the strongest negative influence on germination process due to the higher level of inhibition – up to 44 % of undeveloped seeds in one series.

The observed defects of species structure may be considered to be appeared as a result of the negative action of allelochemicals presented in the prepared extracts. The processed results led to defining major tendencies. Firstly, the extract of *A. retroflexus* had the lower suppressing influence on the investigated species. While the effect of *C. arvense* revealed in inhibition of both radicals and plumules development. The extract of *B. vulgaris* mostly influenced on plumules by reducing their development (up to 16 % of affected seedlings in each replication).

A. absinthium suppressed radicals growth by twisting 12 % of all spouts, and additionally, the radicals withering was observed for all cultivars of *Amaranthus*.

By summarizing the results of this investigation concerning morphological changes and suppression rate, it is possible to appreciate *A. caudatus* as the most vulnerable, and *A. paniculatus* as the most influence-resistant plants.

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Received 01 October 2014.

О. С. Штика[1], Т. І. Білик[2], О. Л. Андрущенко[3]. Оцінка алелопатичної активності як важливий етап при розробці фіторемедіаційної технології

[1, 2]Національний авіаційний університет, просп. Космонавта Комарова, 1, Київ, Україна, 03680

[3]Національний ботанічний сад ім. М.М.Гришка НАН України, вул. Тімірязєвська, 1, Київ, Україна, 01014

E-mails: [1]olga.shtyka@gmail.com; [2]larus_2010@ukr.net; [3]novaflora@ukr.net

Фіторемедіація вважається перспективною технологією очищення та відновлення забрудненого ґрунту. Проте існують фактори, які здатні впливати на процес очищення, значно зменшуючи його ефективність. Інтродування фіторемедіантів у фітоценоз на території забруднення може спричиняти активізацію алелопатичної активності місцевих видів рослин. Алелопатична активність рослин проявляється як секреція вторинних метаболітів у навколишнє середовище у формі летких сполук, ексудатів, які інгібують розвиток інших сусідніх рослин. У цій публікації оцінено алелопатичну активність водорозчиних екстрактів *Amaranthus retroflexus* L., *Cirsium arvense* L., *Barbarea vulgaris* R. Br. та *Artemisia absinthium* L., а також їхній вплив на обрані фіторемедіанти за допомогою біотестування та тесту на пророщування.

Ключові слова: алелопатія; біотестування; водорозчинні екстракти; інтродуковані види рослин; тест на пророщування; фіторемедіація

О. С. Штыка[1], Т. И. Билык[2], О. Л. Андрущенко[3]. Оценка аллелопатической активности как важный этап при разработке фиторемедиационной технологии

[1, 2]Национальний авиационный университет, просп. Космонавта Комарова, 1, Киев, Украина, 03680

[3]Национальний ботанический сад им. Гришко НАН Украины, ул. Тимирязевская, 1 Киев, Украина, 01014

E-mails: [1]olga.shtyka@gmail.com; [2]larus_2010@ukr.net; [3]novaflora@ukr.net

Фиторемедиация считается перспективной технологией очистки и восстановления загрязненной почвы. Однако, существуют факторы, способные влиять на процесс очистки, значительно уменьшая его эффективность. Интродуцирование фиторемедиантов в фитоценозе на территории загрязнения может вызывать активизацию аллелопатической активности местных видов растений. Аллелопатическая активность растений

проявляется как секреция вторичных метаболитов в окружающую среду в форме летучих соединений, экссудатов, которые ингибируют развитие других соседних растений.
В данной публикации оценены алелопатическая активность водорастворимых экстрактов *Amaranthus retroflexus* L., *Cirsium arvense* L., *Barbarea vulgaris* R. Br. и *Artemisia absinthium* L., а также их влияние на выбранные фиторемедианты методоми биотестирования и теста на проращивание.
Ключевые слова: аллелопатия; биотестирование; водорастворимые экстракты; интродуцированные виды растений; ростовой тест; фиторемедиация

Shtyka Olga. PhD student.
Department of Ecology, National Aviation University, Kyiv, Ukraine.
Education: National Aviation University, Kyiv, Ukraine (2010).
Research area: technologies of soil decontamination.
Publications: 30.
E-mail: olga.shtyka@gmail.com

Bilyk Tetyana. Candidate of Biology. Associate Professor.
Department of Ecology, National Aviation University, Kyiv, Ukraine.
Education: Donetsk State University, Donetsk, Ukraine (1980).
Research area: environment toxicology.
Publications: 45.
E-mail: larus_2010@ukr.net

Andrushchenko Olena. Candidate of Biology. Sc. worker.
Department of New Plants, M. M. Gryshko National Botanic Garden, Kyiv, Ukraine
Education: Taras Shevchenko National University of Kyiv, Kyiv, Ukraine (1996).
Research area: acclimatization and selection of plants.
Publications: 35.
E-mail: novaflora@ukr.net