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Ecological Aspects of Allelopathic Interactions of Energy Crops

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ABSTRACT

The allelopathic potential of classical energy crops (*Panicum virgatum* L., *Sorghum saccharatum* (L.) Moench, hybrids 'Zubr' and 'Medovyi') was studied by the energy of germination of biotesters' seeds and their biometric parameters, as well as the selection of sensitive biotesters and test traits. *Secale cereale* L. and *Raphanus sativus* L. var. *radicula* Pers. were used as biotesters. The selectivity of secretions action has been proven – the aqueous extracts from the same energy plant caused different reactions in acceptor plants. The obtained results indirectly indicate the allelopathic potential of energy crops *P. virgatum* and *S. saccharatum*. A decrease in the germination energy of the biotester *R. sativus* var. *radicula* seeds as well as reduction of underground and aboveground parts of both *R. sativus* var. *radicula* and *S. cereale* were observed under the effect of aqueous extracts of studied energy crops. In order to confirm an allelopathic potential of energy crops, using multiple test signs of different biotesters is suggested.

Keywords: allelopathy, classic energy crops, biotesters, *Secale cereale, Raphanus sativus*

INTRODUCTION

Until recently, the literature mostly discussed the environmental and economic benefits of energy crops growing, but now scientists identify a number of associated risks: the impact on land and water resources, biodiversity, changes in agriculture [Pidlisnyuk and Kolisnyk, 2013; Renewable energy in Europe..., 2019; Williams and Feest, 2019]. Allelopathy is one of the potential important risks associated with the growth of energy crops. Allelopathy is a powerful natural factor that influences growth, productivity, durability, species composition of natural and cultural cenoses [Gospodarenko and Lysyansyi, 2015].

Currently, allelopathy is regarded as a factor that performs a regulatory function in the phytocenotic relationships [Polyak and Sucharevych, 2019]; as a form of ecological competition between organisms in phytocenoses [Lysenko et al., 2010]; decisive factor in the formation of the phytocenosis [Symagina and Lysyakova, 2011]; a stabilizer that prevents penetration of other species and populations [Trezzi et al., 2016]; part of the eternal and continuous cycle of organic matter in the biosphere [Muhl and Roelke, 2018], a perspective for weed control [Kondratiev et al., 2017].

Agrocenoses – as monodominant systems – are dangerous for the environment, as they are able to destroy natural connections, impoverish biodiversity, reduce the resilience of crops to adverse environmental conditions. The anthropogenic interference in the functioning of agrophytocenoses enhances this effect [Trezzi et al, 2016; Malovanyy et al., 2019; Tymchuk et al., 2020]. It is known that the use of monocultures leads to the adsorption of certain stable physiologically active substances by the soil-absorbing complex, which has a one-sided, prolonged, allelopathic effect and can significantly inhibit the growth and development of subsequent crop [Trezzi et al, 2016; Muhl and Roelke, 2018]. Allelopathy, as a form of plant interaction in agrocenoses, is sufficiently described unlike the energy crops [Gorelov et al., 2017].

The aim of the study was to evaluate the chemical impact of classical energy crops as a potential transformer in agroecosystems. The tasks were as follows: i) determining the allelopathic activity of energy crops by the germination energy of biotesters seeds and their morphometric parameters; ii) identifying sensitive biotesters and test traits.

MATERIALS AND METHODS

The leaves and stems of the following energy crops: millet (switchgrass) (*Panicum virgatum* L.), sugar sorghum (*Sorghum saccharatum* (L.) Moench) hybrids 'Zubr' and 'Medovyi' were used. The plants were grown on grey forest heavy loam soils of the Bukovinian state agricultural research station, National Academy of Agrarian Sciences of Ukraine. The energy crops were grown under different conditions (Table 1).

Aqueous extracts were prepared from the leaves and stems of the studied plants. The plant material (10 g) was ground, poured with distilled water (100 ml), and infused for 24 h at room temperature (+ 23°C). The aqueous extracts were filtered through a paper filter and used as a solution for irrigation. The choice of such a ratio (1:10), on the recommendation of A M. Grodzinsky [1973], corresponds to the natural conditions that arise in phytocenoses during medium rain.

The allelopathic activity of energy crops was studied using test objects – sowing rye (*Secale cereale* L.) and sowing radish of Red with a white tip variety (*Raphanus sativus* L. var. *radicula* Pers.). The biotesters that were watered with distilled water served as controls, whereas those that were watered with aqueous extracts of leaves or stems of energy crops were experimental options.

Seeds of test objects (100 pcs.) were germinated in Petri dishes on filter paper, watered with water / extract (5 ml) and placed in a thermostat for 3 days at a temperature of +25°C. Further germination (within 10 days) was performed in the cultivation room (+23°C, relative humidity – 70%). Seed germination energy (on the 4th day) [DSTU, 2002] and morphometric parameters: root and aboveground part length (on the 10th day) were studied.

The experiment was repeated four times. Microsoft Office Excel 2003 and Statist computer application packages were used for the statistical processing of the obtained results. Statistical significance was determined based on Student's t-test ($p < 0.05$).

RESULTS AND DISCUSSION

Seed germination is one of the most difficult stages in plant ontogenesis. The study of germination energy of biotester seeds is a common parameter both for determining the effectiveness of new types of fertilizers and for identifying the allelopathic effect [Shevchuk and Agurova, 2011; Gospodarenko and Lysyanskyi, 2015; Yashchuk, 2017]. The obtained results showed that germination energy depended on the energy crop species, the vegetative organ from which the extract was made and the species of biotester. Thus, affected by the extracts from the leaves of *P. virgatum*, the germination energy of *S. cereale* seeds was at the level of control, and in *R. sativus* var. *radicula* in some cases was lower by an average of 32% (Fig. 1).

It is known from the literature, that the width between rows of *P. virgatum* is an important factor that influences the yield [Kulyk, 2014]. He proved that the wide-row method of sowing compared to the narrow-row method contributed to higher yields. In the conducted studies, plant spacing in rows and plant density of *P. virgatum* crop did not influence the allelopathic activity. The extract from the stems of *S. saccharatum* hybrid 'Zubr' caused a decrease by 12–37% of germination energy of *R. sativus* var. *radicula* (Fig. 2).

For the extracts from the vegetative organs of hybrid 'Medovyi', slightly different results were observed. In particular, the extracts from the leaves of plants (Fig. 3A), which grew: without fertilizers, with the application of $N_{60}P_{60}K_{60}$ and

Table 1. Experimental conditions of energy crops growing

Energy crops	Year of vegetation	Conditions of growing
Panicum virgatum L.	4th	Row spacing: 15, 30 and 45 cm
Sorghum saccharatum (L.) Moench	1st	Fertilizing background: • no fertilizers; • with microfertilizers; • with macrofertilizers $N_{60}P_{60}K_{60}$, $N_{90}P_{90}K_{90}$, $N_{120}P_{120}K_{120}$

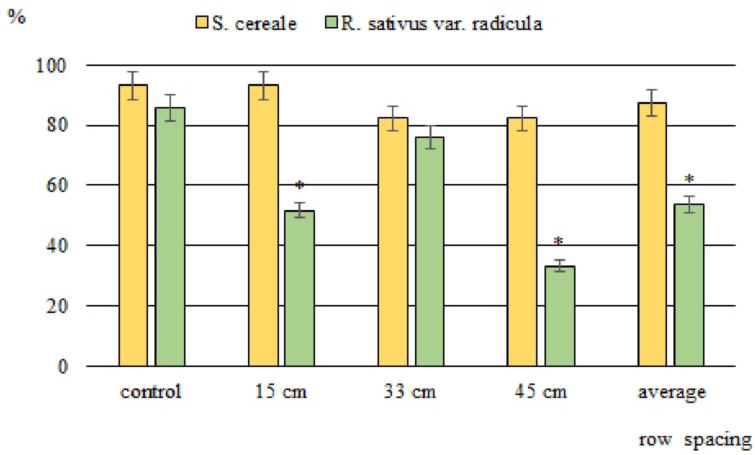


Figure 1. The germination energy of the biotester seeds watered by aqueous extract from *Panicum virgatum* L. leaves

Note: * – hereinafter – a statistically significant difference at $p < 0.05$

$N_{120}P_{120}K_{120}$ caused a decrease in the germination energy of *R. sativus* var. *radicula* by 16–27%.

Extracts from the stems of the hybrid (Fig. 3B) under the three conditions of growing: without fertilizers, with $N_{90}P_{90}K_{90}$ and $N_{120}P_{120}K_{120}$ led to a decrease in the germination energy of the seeds of the biotester by 12 – 30% (on average – 13,9%). At the same time, the germination energy of *S. cereale* did not change.

Multidirectional effects of plant extracts on germination energy and seed germination of biotesters are known. In the laboratory, it was proven that the aqueous extracts from the remains of winter wheat, barley, peas, corn, sunflower and spring rape helped to increase the energy of germination of spring rape seeds. The laboratory germination of oilseed flax also increased under the action of aqueous extracts from soybeans, corn and peas [Koval and Yeshchenko, 2011]. However, many studies state the inhibitory effect of plant extracts on performance. In particular, the extracts from *Miscanthus transmorrisonensis* were toxic to seed germination of various bioindicators. According to Shevchuk and Agurova [2011], the aqueous extracts from underground organs of *Silybum marianum* at concentrations of 1:1 and 1:100 reduced the germination and germination energy of seeds of *Elytrigia elongata* by 15%, and in *Medicago sativa* 'Veselopodolaynskaya' – by 30%. In addition, the extracts at a concentration of 1:10 did not change the germination and germination energy of seeds of these species. Gospodarenko and Lysyankyi [2015] have discovered that the aqueous extracts from the biomass of white mustard, oilseed radish, spring vetch and buckwheat reduce the energy of germination of winter wheat seeds. Significant negative influence of allelochemicals from bird's-foot

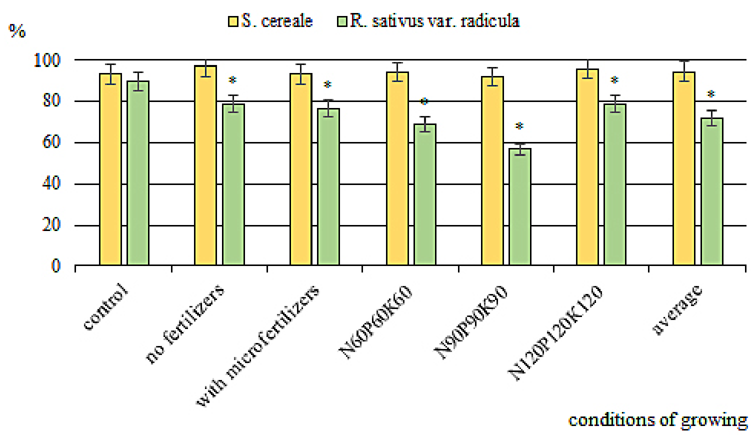


Figure 2. Germination energy of biotesters affected by the aqueous extract from the stems of *Sorghum saccharatum* (L.) Moench hybrid 'Zubr'

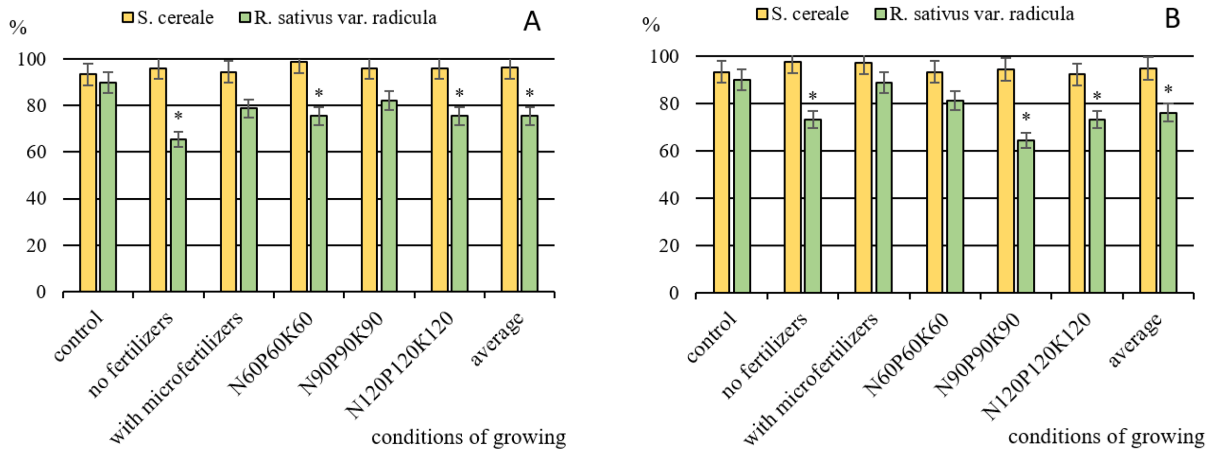


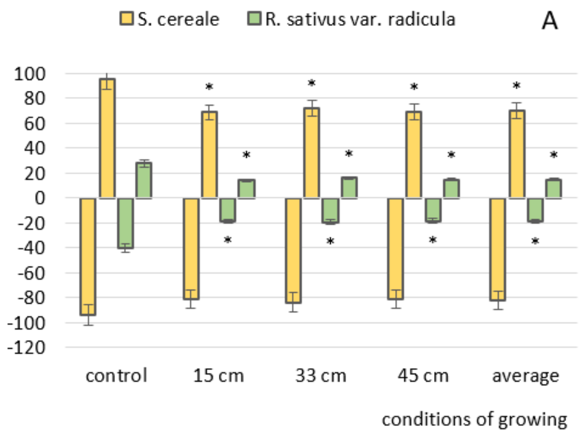
Figure 3. Germination energy of biotesters under the action of an extract from the leaves (A) and stems (B) of *Sorghum saccharatum* (L.) Moench hybrid 'Medovyi'

trefoil organs on germination of gramineous plants seeds (germination decreased by 11–12% compared to control) and allelochemicals from gramineous plants organs on the germination of bird's-foot trefoil seeds (the indicator decreased by 5–11%) was proved [Yashchuk, 2017].

According to recent studies [Siyar et al., 2018], the aqueous extracts of weeds (*Avena fatua, Melilotus officinalis, Polygonum hissaricum*) in different concentrations reduce the germination of seeds of wheat varieties. Studies [Majeed et al., 2017] show that different parts of sugar cane have both stimulating and inhibitory effects on wheat germination. High-concentration root and stem extracts promoted germination, while leaf extract inhibited this process. Varying reaction of biotesters to extracts from different organs of the same energy culture may indicate different content of water-soluble allelopathically active compounds in them. The assumptions made by the authors were confirmed by the results, received by other scientists on the distribution of allelopathically active substances in the plant body. The most allelochemicals are concentrated in the leaves and generative organs, whereas 1.6–9 times lesser amounts are found in the roots [Scavo et al., 2018]. Korolyova and Lychko [2017] found that the green vegetative mass of *Grindelia squarrosa* contains relatively more allelopathic substances, fewer inflorescences and the least roots. Yunosheva [2017] proved that high activity of lavender allelochemicals is characteristic for leaves, lower – for inflorescences, weak – for roots. However, the inhibitory effect of the aqueous extracts of the *Araceae* family members on the growth of watercress roots was manifested in the following sequence: fruits > roots > leaflets > seedlings. Baleev and Buharov [2011] give a rating series in ascending order of allelopathic parsley root extracts effect: root – stem – leaves – seeds – flowers. Thus, in the initial stages of germination, *S. cereale* seeds did not respond to the action of aqueous extracts from the vegetative organs of energy crops, which is probably due to either the concentration of the extract used (1:10) or the tolerance of biotester seeds to allelochemicals of the studied crops. Instead, the germination energy of *R. sativus* var. *radicula* decreased under the action of aqueous extracts from the leaves of *P. virgatum* and *S. saccharatum* hybrid 'Medovyi', as well as from the stems of *S. saccharatum* hybrids 'Zubr' and 'Medovyi', so it can be assumed that these cultures have allelopathic potential, and *R. sativus* var. *radicula* – sensitive biotester.

At the next stage, the allelopathic activity of energy crops was analyzed by morphometric parameters of biotester seedlings. Different sensitivity of morphometric parameters of biotesters to allelochemicals of energy crops was observed. Thus, the length of the underground part of *S. cereale* was at the level of control, and *R. sativus* var. *radicula* almost 50% shorter under the influence of extracts from the leaves of *P. virgatum* (Fig. 4A). However, the length of the aboveground part of *S. cereale* decreased by an average of 37% compared with the control, and *R. sativus* var. *radicula* – more than 50%.

A similar trend was observed under the influence of the extracts from the stems of *P. virgatum* (Fig. 4B). No changes in indicators depending on the applied agronomic techniques were detected. Under the influence of the extracts from



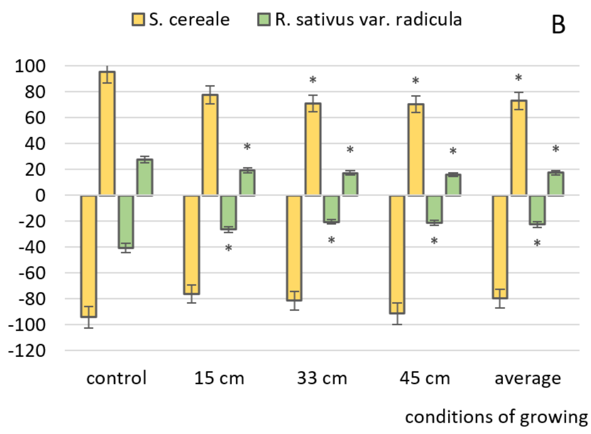


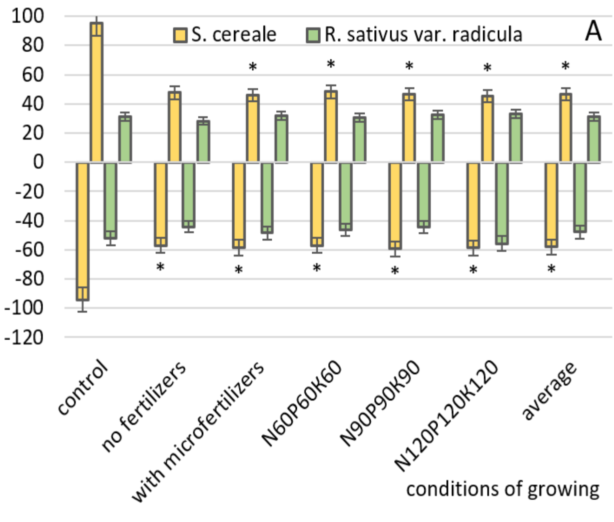
Figure 4. The length of the aboveground (upper part of the diagrams) and underground (lower part of the diagrams) parts of biotesters influenced by the extracts from the leaves (A) and stems (B) of *Panicum virgatum* L.

the vegetative organs of *S. saccharatum* hybrid 'Zubr' (Fig. 5) inhibition of the growth processes of both the root and the aboveground part of *S. cereale* in all variants was observed. The length of the underground part of plants decreased on average by 39 %, and the aboveground by 51% compared with the control both for the extract from the leaves (Fig. 5A) and the stems (Fig. 5B). The morphometric parameters of *R. sativus* var. *radicula* did not change, only in the case of using an extract from the stems of *S. saccharatum* inhibition of growth of the underground part by 30 % under the conditions of growing with macrofertilizer $N_{90}P_{90}K_{90}$ was observed.

S. saccharatum hybrid 'Medovyi' showed a similar trend (Fig. 6). A clear decrease in the growth of both the roots of *S. cereale* by 40% and the length of the aboveground part by 51% was observed. Moreover, this effect did not depend either on the agrochemical conditions of cultivation of *S. saccharatum* or on the organ the extract was made from.

Thus, the inhibitory effect of aqueous extracts from the vegetative organs of *S. saccharatum* hybrids 'Zubr' and 'Medovyi' on the growth processes of the aboveground and underground parts of *S. cereale* seedlings was shown. That is, it can be assumed that *S. saccharatum* has an allelopathic effect.

Gospodarenko & Lysyanskyi [2015] proved the inhibitory effect of the white clover extract and the stimulating effect of aqueous extracts from white mustard biomass, oil radish, spring vetch and buckwheat on the length of winter wheat seedlings. Stimulation of the growth of embryonic roots of *Lotus corniculatus* by 9–14% under



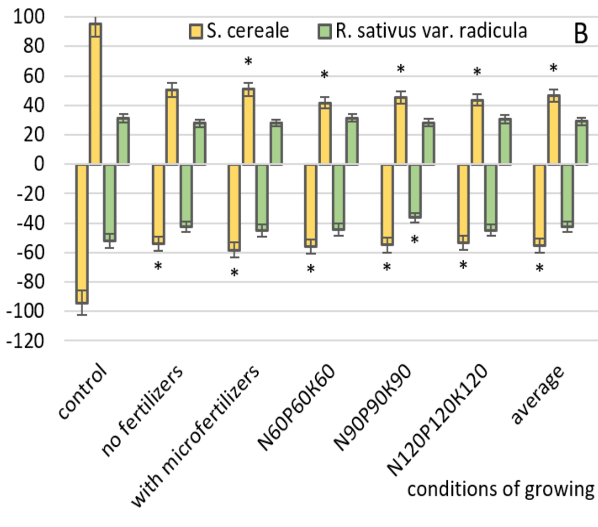


Figure 5. The length of the aboveground (upper part of the diagrams) and underground (lower part of the diagrams) parts of biotesters influenced by the extracts from the leaves (A) and stems (B) of *Sorghum saccharatum* (L.) Moench hybrid 'Zubr'

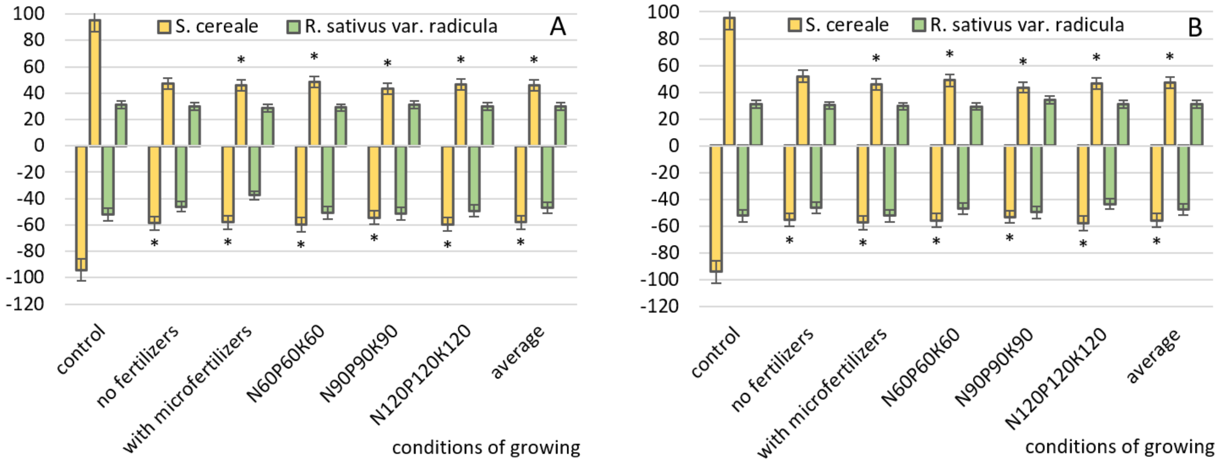


Figure 6. Length of aboveground (upper part of diagrams) and underground (lower part of diagrams) parts of biotesters influenced by the extracts from leaves (A) and stems (B) *Sorghum saccharatum* (L.) Moench hybrid 'Medovyi'

the influence of allelochemicals from extracts of vegetative and root mass of gramineous plants of grasses was proven [Yashchuk, 2017]. According to the recent studies [Siyar et al., 2018], the length of the roots and shoots of wheat varieties showed different reactions to aqueous extracts of weeds. Studies [Majeed et al., 2017] have shown that the extracts of roots and stems of sugarcane in high concentrations contributed to the growth of seedling roots, while the extract from the leaves had a negative effect on this parameter.

Gorelov et al. [2017] noted that *Miscanthus*×*giganteus* and various species of *Salix* did not show significant allelopathic activity. However, a long drought period led to the accumulation of allelopathically active substances in the soil under energy crops, which inhibited the growth of test crops.

CONCLUSIONS

The obtained results indirectly indicate an allelopathic potential of the *Panicum virgatum* L. and *Sorghum saccharatum* (L.) Moench energy crops. A decrease in the germination energy of the biotester *R. sativus* var. *radicula* seeds and reduction of underground and aboveground parts of both *R. sativus* var. *radicula* and *S. cereale* were observed under the effect of aqueous extracts of the studied energy crops. In order to confirm an allelopathic potential of energy crops, using multiple test signs of different biotesters is suggested. It was assumed that long-term cultivation of energy crops on a certain area can lead to the accumulation of allelochemicals in the soil and to the 'sick soil syndrome'.

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