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SEED GERMINATION AND INITIAL GROWTH OF WINTER RAPE WATERED WITH EXTRACTS FROM CROP RESIDUES, SELF-SEEDINGS, AND SOIL AFTER WINTER RAPE CULTIVATION

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Abstract. The aim of the study was to assess the effect of water extracts from crop residues and self-seedings of winter rape and soil extracts after its harvesting on the germination energy and capacity, as well as initial growth of winter rape under laboratory conditions. In first part of research the influence of different extracts (from: a – stems, b – siliques and c – young plants of winter rape) at three concentrations: (0.25; 0.5 and 1%) was examined. Control (0%) was watered with distilled water. In second part of research the effect of soil extracts from fields under crop with different proportions of winter rape in crop rotation (0, 33, 66 and 100%) was examined. The seeds watered with self seeding winter rape extracts in comparison with siliques and stems extracts were characterized by a significantly worse germination energy and capacity. In addition the seedlings had the significantly smaller height and the shorter seedling roots. Independently of the kind of extract, significantly worse results of seed germination and initial growth of winter rape seedlings were observed along with an increase in winter rape extract concentrations. It was found that the soil extracts after 3-year winter rape monoculture significantly reduced germination energy and length of seedling roots and also caused tendencies for smaller germination capacity and seedling height in comparison with those watered with extract from soil where rape was not grown for last 3 years and with distilled water.

Keywords: allelopathy, autotoxicity, germination energy and capacity, one-crop system

INTRODUCTION

Flora of agrobiocenoses not only takes up nutrients but also, like other organisms, releases chemical compounds into the environment. Some of them are biologically active. That is why they are called allelocompounds, and the whole of reactions that occur with their participation – allelopathy. Allelochemical action on the germination, growth, development and yield of plants is more often unfavorable, less frequently –

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especially in minimal concentrations – stimulating [Stupnicka-Rodzynkiewicz 1970, Duer 1988, 1996, 1997b, Oleszek 1994, Jaskulski 1997, 1999, Gawroński 2004].

Releasing allelocompounds takes place in the course of growth, but their main source in biocenoses are decomposing plant residues [Oleszek 1994, Duer 1997b]. The destruction of tissues results in releasing and leaching of those substances to soil [Oleszek 1995]. Plant residues are mostly decomposed biologically, and that is why also metabolites of microflora take part in allelopathic activity [Wójcik-Wojtkowiak 1987]. Allelopathic potential depends on the plant age and is higher in young plants, while it falls as they rich full maturity [Wójcik-Wojtkowiak *et al.* 1998]. Plants of the family Brassicaceae contain glucosinolates which in the glycosidic form do not show allelopathic activity. In case of damage to the tissue, glucosinolate hydrolysis occurs, and its products are essential oils that inhibit germination and the growth of wheat seedlings [Biały *et al.* 1990]. During proper crop rotation of field plants, the risk of accumulation of allelocompounds in soil is small, but in monocultures it is the basic cause of soil sickness. Crop residues or self-seedings may be a source of many inhibitors of plant germination and growth [Wu *et al.* 2007, Andruszczak *et al.* 2009].

The lack of data concerning the autotoxicity of glucosinolates in winter rape was a motive for undertaking this study, which aimed to estimate the effect of extracts from crop residues, self-seedings of winter rape and soil extracts from fields with its different proportion in crop rotation on the germination energy and capacity of seeds, as well as on the initial growth of winter rape seedlings.

MATERIAL AND METHODS

The experiment was carried out in 2009 in the laboratory of the Department of Agricultural Ecology of the University of Life Sciences in Lublin in two series with 4 replications each. In the first series, water extracts were made using distilled water and cut plant material of winter rape in appropriate proportions (1 g D.M. of plant material per 100 ml of water = 1%). The mixture was left for two days and sieved through filter paper. The first experimental factor was the kinds of extracts: a – from stems of winter rape, b – from siliques of winter rape and c – from winter rape plants at the stage of 1-4 leaves (BBCH 11-14). Obtained solutions were diluted to appropriate concentrations, which made the second factor in this series: 1 – 0%; 2 – 0.25%; 3 – 0.5% and 4 – 1%. The control plates were watered with distilled water.

Winter rape was grown in crop rotation there. In the second series the examined extracts were made from soil collected from a field experiment conducted in 2007-2009 on the Experimental Farm at Bezek near Chełm (51°19' N; 3°25' E) with its various proportions (33, 66 and 100%) on the mixed rendzina (class IIIb, the defective wheat complex). Extracts were prepared from soil collected from the layer 0-20 cm directly after the harvest of: a – winter rape sown for 3 years continuously; b – winter rape from a 2-year monoculture; c – from plots where winter rape was grown alternately with winter wheat; d – from a field after wheat where rape was not grown for the lats three years; e – the control – distilled water. Water extracts were prepared using distilled water and soil (after screening it through a sieve with a mesh of 1 mm) in the ratio of 2:1. The mixture were shaken for 5 hours, centrifuged and filtered.

Seeding material of winter rape was placed in Petri dishes, 50 seeds in each, with a diameter of 10 cm on the substrate of two layers of filter paper and watered with 15

ml of extract daily. The constant temperature 22°C was maintained throughout the experiment. Activity assessment of the applied extracts was made after 4 days – determining germination energy – and after 8 days: germination capacity, the length of rootlets and the height of the seedling.

The obtained results were subjected to the statistical analysis with the variance analysis method, regarding as significant the differences which were proved with a risk of error less or equal to 5%, and their significance was verified with Tukey's test. Calculations were made using the original statistical program ARSTAT, created in the Department of Mathematics and Computer Science Applications of the University of Life Sciences in Lublin.

RESULTS

One of the most important parameters of seeding material which determine even and fast plant emergences and a proper stand density are germination energy and capacity. Significant differences of those features of seeding material of winter rape were indicated depending on the kind of the extract, its concentration and also in interaction between those factors (Tables 1, 2). All the extract concentrations significantly limited the germination energy of winter rape seeds in comparison with distilled water. Germination energy decreased significantly along with an increase in the concentration of the used extracts (Table 1). After the next 4 days those differences decreased, since a significantly less germination capacity in comparison with the control occurred only where the concentrations 0.5 and 1% were applied (Table 2). Irrespective of the level of concentration, the extract from young plants of winter rape plants had a significantly greater effect decreasing the germination energy and capacity of winter rape seeds as compared with the extracts from its stems and seed siliques (Tables 1, 2). This observation is confirmed by significant differences in interaction between the extract concentration and its kind, where extracts from young rape plants with concentrations of 1% and 0.5% caused a significant decrease in germination energy in the studied material to the levels 11.2 and 32%, respectively (Table 1), and the extract with a concentration of 1% additionally reduced germination capacities to 50.4% (Table 2).

Table 1. Germination energy of winter rape seeds, %
Tabela 1. Energia kiełkowania nasion rzepaku ozimego, %

Extract kind* Rodzaj wyciągu	Extract concentration – Stężenie wyciągu, %				Mean – Średnia
	0	0.25	0.50	1.00	
a	85.6	76.0	72.8	72.8	76.8
b	80.8	71.2	72.8	58.4	70.8
c	76.0	60.8	32.0	11.2	45.0
Mean – Średnia	80.8	69.3	59.2	47.5	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:					
extracts – wyciągów		8.3			
concentrations – stężeń		10.6			
interactions – interakcji		23.7			

*a – from stems of winter rape – z łodyg rzepaku ozimego
b – from siliques of winter rape – z łuszczyn rzepaku ozimego
c – from young plants of winter rape – z młodych roślin rzepaku ozimego

Table 2. Germination capacity of winter rape seeds, %
Tabela 2. Zdolność kiełkowania nasion rzepaku ozimego, %

Extract kind* Rodzaj wyciągu	Extract concentration – Stężenie wyciągu, %				Mean – Średnia
	0	0.25	0.50	1.00	
a	95.2	94.4	96.0	98.4	96.0
b	93.6	91.2	92.8	91.2	92.2
c	99.5	88.0	75.2	50.4	78.4
Mean – Średnia	96.3	91.2	88.0	80.0	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:					
extracts – wyciągów		8.0			
concentrations – stężeń		10.2			
interactions – interakcji		22.7			

* explanations see Table 1 – objaśnienia pod tabelą 1

Water extracts made from different parts of winter rape had a significant effect on the length of the rootlet and the height of seedlings of this species. Seedlings watered with the extract from young plants of winter rape were significantly lower and had significantly shorter rootlets than seedlings watered with extracts from stems and siliques of winter rape (Tables 3, 4). Irrespective of the kind of extract, 1% not diluted extracts, which caused a significant inhibition of the growth of winter rape seedlings and their roots had the strongest inhibitory action in comparison to the control seedlings. Like in the assessment of germination energy and capacity, extracts from young plants of winter rape with concentrations of 0.5 and 1% showed significantly the greatest inhibitory effect on the elongation growth of the stem and roots of seedlings.

Table 3. Height of winter rape seedling, cm
Tabela 3. Wysokość siewki rzepaku ozimego, cm

Extract kind* Rodzaj wyciągu	Extract concentration – Stężenie wyciągu, %				Mean – Średnia
	0	0.25	0.50	1.00	
a	5.1	5.5	5.5	4.2	5.1
b	4.7	4.9	5.2	4.1	4.7
c	5.3	4.3	1.7	0.9	3.1
Mean – Średnia	5.0	4.9	4.2	3.1	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:					
extracts – wyciągów		0.7			
concentrations – stężeń		0.8			
interactions – interakcji		1.9			

* explanations see Table 1 – objaśnienia pod tabelą 1

The analysis of results obtained in the second series of the experiment showed a significant decrease in the germination energy of winter rape seeding material as well as shortening of roots of its seedlings under the influence of the soil extract after 3-year monoculture of this field plant in comparison with seedlings watered with distilled water and the extract from soil on which rape or other Brassicaceae plants were not grown for the last 3 years. Seeds watered with the soil extract after 3-year monoculture of winter rape were also characterized by the least germination capacity, and the seedlings grown from them were the lowest, but these differences were statistically non-significant and had only a character of a tendency (Table 5).

Table 4. Rootlet length of winter rape, cm
Tabela 4. Długość korzenia zarodkowego rzepaku ozimego, cm

Extract kind* Rodzaj wyciągu	Extract concentration – Stężenie wyciągu, %				Mean – Średnia
	0	0.25	0.50	1.00	
a	6.1	5.7	5.3	2.8	5.0
b	5.6	4.5	4.7	2.8	4.4
c	5.8	3.3	1.0	0.2	2.6
Mean – Średnia	5.9	4.5	3.7	1.9	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:					
extracts – wyciągów		1.1			
concentrations – stężeń		1.4			
interactions – interakcji		3.1			

* explanations see Table 1 – objaśnienia pod tabelą 1

Table 5. Effect of soil extracts on germination of winter rape seeds
Tabela 5. Oddziaływanie wyciągów z gleby na kiełkowanie nasion rzepaku ozimego

Characteristic – Cecha	Kind of soil extract – Rodzaj wyciągu glebowego					$LSD_{0.05}$ $NIR_{0,05}$
	a*	b	c	d	e	
Germination energy, % Energia kiełkowania, %	72.5	80.7	82.1	84.5	81.0	10.1
Germination capacity, % Zdolność kiełkowania, %	86.9	88.6	98.4	99.0	96.5	ns – ni
Height of seedling, cm Wysokość siewki, cm	4.1	4. 9	4.7	5.4	5.0	ns – ni
Rootlet length, cm Długość korzenia, cm	3.3	4.0	4.6	4.9	4.9	1.4

* a – from 3-year monoculture of winter rape – z 3-letniej monokultury rzepaku ozimego
b – from 2-year monoculture of winter rape – z 2-letniej monokultury rzepaku ozimego
c – from field where winter rape was grown 1 year – z poletek, gdzie rzepak ozimy uprawiany był przez 1 rok
d – from field after winter wheat where winter rape was not grown for last 3 years – z pola po pszenicy ozimej, gdzie rzepak nie występował w ostatnich trzech latach
e – control – distilled water – kontrola – woda destylowana
ns – ni – non-significant differences – różnice nieistotne

DISCUSSION

Inhibitory effect of rape glucosinolates on germination and the initial growth of field crops under laboratory conditions was proved by Waligóra [1996]. In her experiment compounds belonging to the group of glucosinolates not only decreased the number of germinated seeds in lettuce, but also reduced root growths, caused their turning brown and root hair atrophy. Just as in the present study, the power of action was directly proportional to the applied concentration of extracts. The period of action of the extracts counted as well, since their effect on germination energy was greater than that on germination capacity which was assessed after suitable time. The study by Waligóra and Krzymańska [2004] indicated that significant inhibitory action of glucosinolates was shown even where extracts with the lowest concentrations of those compounds were used (0.1% and 0.25%). The seeding material of lettuce, oat and radish turned out to be particularly susceptible to a negative effect of glucosinolates.

The reports of Wójcik-Wojtkowiak *et al.* [1998] concerning a higher allelopathic potential of young plants, decreasing as they achieve full maturity, are confirmed by a significantly stronger negative allelopathy of extracts from the young plants of winter rape against grain germination and a growth of winter rape seedlings than the extracts from siliques and stems, proved in the present study. Decomposing biomass of white mustard placed directly on filtered paper in the study by Jaskulski *et al.* [1997] significantly reduced grain germination and a growth of spring barley seedling. The same biomass subjected to decomposition in soil placed in cuvettes significantly decreased only germination energy, not reducing statistically a growth of seedlings of the test plant. The biomass of yellow lupine and fodder sunflower stimulated growth of spring barley seedlings.

Alam [1990], Wu *et al.* [2007] as well as Andruszczak *et al.* [2009] in their study over cereal autotoxicity proved that water extracts from wheat crop residues inhibited germination and the growth of its seedlings as well as those of winter spelt wheat. The results of a biotest conducted by Duer [1997a] also indicated that the extracts from soil together with roots, crop residues, stubble and straw of winter wheat (3 and 6 $t \cdot ha^{-1}$), irrespective of the time and tools used for mixing with soil, caused a stronger inhibition of winter wheat seedling growth than the extracts from soil without an addition of straw. Nevertheless, a reduction in this effect was observed when crop residues and straw were mixed with soil using a rototiller (as compared with plowing). The author explains that with a higher crushing of organic matter, better mixing with soil and aeration and consequently, its faster microbiological decomposition. Parylak [1997], studying the effect of soil extracts from under winter triticale grown in monoculture and crop rotation on its germination, found tendencies for stimulating action of the extract from under monoculture on germination of triticale grains. At the same time she proved that the examined seedlings watered with the soil extract from a continuous monoculture of winter triticale grow significantly slower than under the influence of the extract from soil where crop rotation was used. A less allelopathic potential of chemical substances released into the environment during plant growth and the decomposition and their biomass then directly of extracts was confirmed by the present author's observations, which show that soil extracts after the 3-year monoculture of rape significantly limited germination energy and the elongation of roots, whereas differences in germination capacity and the height of seedlings were statistically non-significant and had a character of a tendency. Likewise, Kryzevicienė and Paplauskienė [2004], studying the allelopathic potential of phenolic compounds contained in 4 species of grasses on the germination and growth of radish, red clover and white clover, indicated that under laboratory conditions water extracts from the aboveground parts, except rare exceptions, significantly limited seed germination and the growth of the studied plants. Under field conditions the results of emergences and survival rates of white clover and red clover sown in grass species were dubious, especially in late spring during grass flowering, in spite of the largest content of phenolic compounds in them in that period.

CONCLUSIONS

1. A gradual decrease in germination energy and capacity, as well as in the initial growth of winter rape occurred along with an increase in concentration of extracts obtained from different parts of winter rape plants.

2. Extracts from young rape plants showed a significantly higher allelopathic potential against germinating seeds of winter rape, especially in higher concentrations, in comparison with extracts from siliques and stems of winter rape.

3. Soil extracts after 3-year monoculture of winter rape, in comparison with extracts from soil where plants from the family Brassicaceae were not grown recently and in comparison with distilled water, resulted in a decrease in germination energy and the root length, and a tendency to decrease germination capacity and the height of seedlings.

4. Inhibitory effect of the studied extracts on the germination energy and capacity of winter rape seeds decreased along with extending the time of action.

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KIEŁKOWANIE NASION I POCZĄTKOWY WZROST RZEPAKU OZIMEGO PODLEWANEGO WYCIĄGAMI Z RESZTEK POŻNIWNYCH, SAMOSIEWÓW ORAZ Z GLEBY PO JEGO UPRAWIE

Streszczenie. W doświadczeniu badano parametry kiełkowania i początkowego wzrostu rzepaku ozimego podlewanego wodnymi wyciągami z resztek pożniwnych, samosiewów rzepaku ozimego oraz wodnymi wyciągami z gleby po jego zbiorze. Czynnikami doświadczenia były rodzaje wodnych wyciągów z: a) łodyg; b) łuszczyn i c) z młodych roślin rzepaku ozimego oraz ich stężenia: 0,25; 0,5 i 1%. Kontrolę (0%) stanowiła woda destylowana. Dodatkowo w drugiej serii badano wyciągi z gleby z pól o różnym udziale rzepaku ozimego w zmianowaniu: 0, 33, 66 i 100%. Nasiona podlewane wyciągiem z młodych roślin rzepaku wykazywały istotnie mniejszą energię i zdolność kiełkowania, a siewki miały istotnie mniejszą wysokość i krótsze korzenie zarodkowe w porównaniu z podlewanymi wyciągami z łuszczyn i łodyg rzepaku ozimego. Niezależnie od rodzaju wyciągu istotnie słabsze wyniki kiełkowania nasion i początkowego wzrostu siewek rzepaku ozimego odnotowywano wraz ze wzrostem stężenia wyciągów z rzepaku ozimego. Wyciągi z gleby po 3-letniej monokulturze rzepaku ozimego istotnie zmniejszały energię kiełkowania i długość korzeni. Stwierdzono także tendencje do obniżenia zdolności kiełkowania i wysokości siewek w porównaniu z roślinami podlewanymi wodą destylowaną lub wyciągiem z gleby, na której rzepak nie był uprawiany w ostatnich trzech latach.

Słowa kluczowe: allelopatia, autotoksyczność, energia i zdolność kiełkowania, monokultura

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