

DOI: 10.5586/aa.1739

**Publication history**

Received: 2018-01-17

Accepted: 2018-05-25

Published: 2018-06-29

**Handling editor**

Barbara Hawrylak-Nowak,  
Faculty of Horticulture and  
Landscape Architecture,  
University of Life Sciences in  
Lublin, Poland

**Authors' contributions**

RK, HG: experiment design;  
RK, HG, MR, JT: conducting the  
research; HG, MR: analysis of the  
experiment results; HG, RK, MR:  
writing the paper

**Funding**

This research was financially  
supported by the statutory  
funds of the Institute of Soil  
Science and Plant Cultivation –  
Research State Institute.

**Competing interests**

No competing interests have  
been declared.

**Copyright notice**

© The Author(s) 2018. This is an  
Open Access article distributed  
under the terms of the  
[Creative Commons Attribution  
License](#), which permits  
redistribution, commercial and  
noncommercial, provided that  
the article is properly cited.

**Citation**

Gołębiowska H, Kieloch R,  
Rdzanek M, Topolski J. The effect  
of plant extracts from *Solanum  
nigrum* L. and *Avena fatua* L.  
on the growth of some weed  
species and agropathogenic  
fungi. *Acta Agrobot.*  
2018;71(2):1739. [https://doi.  
org/10.5586/aa.1739](https://doi.org/10.5586/aa.1739)

**Digital signature**

This PDF has been certified using digital  
signature with a trusted timestamp to  
assure its origin and integrity. A verification  
trust dialog appears on the PDF document  
when it is opened in a compatible PDF  
reader. Certificate properties provide  
further details such as certification time  
and a signing reason in case any alterations  
made to the final content. If the certificate  
is missing or invalid it is recommended to  
verify the article on the journal website.

## ORIGINAL RESEARCH PAPER

# The effect of plant extracts from *Solanum nigrum* L. and *Avena fatua* L. on the growth of some weed species and agropathogenic fungi

Hanna Gołębiowska\*, Renata Kieloch, Maciej Rdzanek, Jakub Topolski

Institute of Soil Science and Plant Cultivation – Research State Institute, Orzechowa 61, 50-540 Wrocław, Poland

\* Corresponding author. Email: [r.kieloch@iung.wroclaw.pl](mailto:r.kieloch@iung.wroclaw.pl)

**Abstract**

Experiments to evaluate 40% and 80% methanol extracts prepared from the aboveground parts of two *Solanum nigrum* biotypes and from the roots of two *Avena sativa* biotypes were used to test the growth and development of some weed species and agropathogens. The species collected from different crop fields were *Viola arvensis*, *Chenopodium album*, *Stellaria media*, *Papaver rhoeas*, and *Thlaspi arvense* together with the pathogenic fungi *Fusarium avenaceum*, *F. culmorum*, and *F. oxysporum*. Plant morphological changes and significant fresh weight reduction of *Viola arvensis* were observed when treated with both 40% and 80% extracts. A similar response was found in *C. album*, but only when plants were treated with an 80% extract obtained from plants of *S. nigrum* collected from a maize field. The most susceptible to both extracts from *A. fatua* roots growing in a spring wheat field were *C. album* and *S. media*, whereas *V. arvensis* was only susceptible to the 80% extract. The addition of the extracts obtained from *A. fatua* to PDA medium at concentrations of 0.1% and 1% contributed to significant reductions in the mycelium growth of all three *Fusarium* species. The extract obtained from *S. nigrum* added to PDA medium at 1% concentration slightly stimulated mycelium growth of *F. oxysporum*.

**Keywords**

*Fusarium* spp.; weeds; plant extracts; *Avena sativa*; *Solanum nigrum*; growth inhibition

**Introduction**

Crop plants are continuously being selected to improve their agricultural traits characterized by low competitive ability and are treated as alien species in agrophytocoenoses. Both wild plants including segetal weeds and crop species are able to synthesize specific chemical compounds with bioactive effects [1,2]. The majority of these substances can be classified into groups of secondary metabolites such as phenolics, alkaloids, terpenoids, and flavonoids [3: p. 120–124, 139–143] [4: p. 84–90, 266–283, 295–297] [5,6]. They do not play a direct role in plant nutrition but are involved in diverse metabolic processes and also in protecting crop plants against different kinds of pathogens [7–10]. For this reason, they can be primary materials in the production of bacteriostatic compounds, natural pesticides, pharmaceuticals, and supplements for functional foods [11,12].

Plant communities on nonarable lands are a part of natural biocoenoses often with a rather stable species balance. Under favorable conditions, some with a high propagation ability can migrate to adjacent arable fields where their strong competitiveness can be revealed [13: p. 612–678]. These taxa are characterized by a high allelopathic potential

to other plant species as well as to soil microorganisms and, therefore, can be a threat to the ecological balance in agrobiocenoses [5]. They easily establish on fields with a zero-ploughing system characterized by the abundance of crop plant residues in the upper layers of soil. They prefer acidic soils from which uptake and accumulation of heavy metals from fertilizers and pesticides is easier. Rapid adaptation to different habitat conditions is one of the factors affecting the concentration of bioactive substances and enzymatic activity [6], as well as their influence on agrophages, e.g., *Fusarium* fungi, pests, or segetal weeds [14]. Previous studies have reported that intensified production of the secondary metabolites reflected plant reaction to oxidative stress provoked by water or nutrient deficit, too high or too low a temperature, pathogen invasion, mechanical injury, etc. [15–17]. An example of plants with high bioactivity is species from *Solanum* genus, notably *Solanum nigrum* L. The most toxic plant parts are its immature fruits containing glycoalkaloids, which are harmful for human health, and others such as solasodine. Steroidal saponins, solanigrins, and degalactotigonin have also been extracted from whole plants of *S. nigrum*. They have properties similar to cortisone and activity similar to natural insecticides [18]. Highly bioactive are also species from the genus *Avena*, both wild forms, such as *A. strigosa*, *A. abyssinica*, *A. bizantina*, and *A. fatua* L., as well as a cultivated form, namely *A. sativa*. Bioactivity of these species results from the presence of some valuable substances such as flavonoids, nicotinamide, water-soluble silicates, amino acids, peptides, and triterpene saponin – avenacin (A-1, A-2, B-1, B-2) that shows fungicidal activity. Avenacin A-1 exists only in the epidermal cells of roots and, among all avenacins, is the most toxic to fungi [11: p. 213–223] [19]. An example can be the use of the toxic activity of saponin present in alfalfa (*Medicago sativa* ssp. *sativa* L.) to protect hops from some pathogens and insects.

There is no knowledge as to whether the bioactivity of these species is a result of their high propagation and invasiveness or it is derived from the presence of specific substances with synergetic, additive, or inhibitory action. The aim of this present research was to investigate the differences in the effects of extracts from plants of *S. nigrum* and *A. fatua* on some segetal weed species and pathogenic fungi.

## Material and methods

Plant material of *S. nigrum* was collected from maize and potato fields of *A. sativa* collected from spring wheat and maize fields and was used to investigate the bioactivity for some segetal weed species and plant pathogenic fungi. It was obtained from fields with different soil conditions. Both maize fields were located on brown soil with a high organic matter (3.4% and 3.0%) and nutrient contents. The potato and spring wheat fields were located on podzolic soil also with low organic matter (1.2% and 1.3%) and nutrient contents. The experiment was carried out under glasshouse and laboratory conditions.

### Plant material

Plants were collected from untreated plots of arable fields differing in their cultivated crop species. Complete shoots and roots of plants obtained from the field were chopped into small pieces and dried in a cabinet dryer at a temperature of 25–30°C for 60 h. The final water content of the dried material was <10%.

### Preparation of extracts for weed testing and for the antifungal assay

Fifty g of plant dry matter was treated with 250 mL of 80% methanol at room temperature for 24 h. This was then centrifuged in a rotary centrifuge at 125 rpm for 1 hour. The next step was fractionation using the method of extraction to solid phase (SPE) with a C18 filler. Fractionation was initiated with the addition of water to remove sugars from the extract, then 40% methanol was added to obtain the flavonoid fraction, or 80% methanol was added to separate the saponin fraction. The methanol fractions so obtained

were placed in a rotary evaporator to evaporate off the solvent. The dry residue of each fraction was dissolved in 100 mL of water for testing on the weed species or 100 mL of dimethylsulfoxide (DMSO) for the antifungal assay. The extract was stored at 4°C.

#### Examination of extract effect on weeds

In order to evaluate the inhibitory effects of the plant fractions extracted (saponins and flavonoids), a glasshouse experiment was set up to test on the selected weed species. The test species were: *Viola arvensis* Murr., *Chenopodium album* L., *Stellaria media* L., *Papaver rhoeas* L., and *Thlaspi arvense* L. The experimental design was a completely randomized blocks pattern with three replications. Seeds of the weed species were sown onto 15-cm diameter pots filled with a mixture of 2:1 peat:sand (v/v). Soon after seedling emergence, they were thinned to leave five plants per pot. When they had reached the four-five-leaves growth stage, they were sprayed with the prepared extracts. The treatment was carried out using a laboratory sprayer (Aporo) fitted with a beam equipped with flat fan nozzles (TeeJet XR 11003-VS). The nozzles were operated at a pressure of 200 kPa and a speed of 2.5 km h<sup>-1</sup> producing a spray volume of 250 L ha<sup>-1</sup>.

Phytotoxicity evaluation, including the degree and type of injury, was carried out 2 weeks after treatment. It was recorded using a 9-point scale, where: 1 – no injury, 2 – very slight symptoms, 3 – slight symptoms, 4 – strong symptoms, 5 – slight injuries, 6 – pronounced injuries, 7 – strong injuries, 8 – very strong injuries, 9 – total plant destruction. Four weeks after spraying, plants were harvested and the fresh weights of weed shoots was recorded. The efficacy of the extracts was determined based on fresh weight loss as a result of the extract spraying by comparison with untreated plants. The data were subjected to analysis of variance using Statgraphics (Microsoft).

#### Examination of extract effects on *Fusarium* fungi

The effect of the plant extracts on fungal growth was performed under laboratory conditions using the standard “poisoned food technique” (see [20]). The pathogenic fungi *F. oxysporum* Schlecht, *F. culmorum* (W. G. Sm.), and *F. avenaceum* (Fr.) Sacc. were isolated in 2016 from maize plants exhibiting the typical symptoms of fusariosis. Fragments of infected plants were disinfected in 0.5% sodium hypochlorite for 1 minute and then cut to produce inocula that were plated onto PDA medium (potato dextrose agar). After incubation at room temperature, growing colonies of fungi were transferred to standard tubes with PDA medium. They were identified taxonomically using monographic keys. Plant extracts were tested at concentrations of 0.1% and 1%. The extracts dissolved in DMSO were introduced into cooled PDA medium at given concentrations and, after thorough mixing, they were poured onto Petri dishes. In order to eliminate bacteria from the PDA medium, an antibiotic (tetracycline, 20 µg mL<sup>-1</sup>) was added. After medium solidification, a 10-mm diameter disc of the fungi was placed in the center of each Petri dish. Discs were cut from the edges of 10-day cultures of the fungi growing on PDA medium. Radial growth of mycelium was measured every day until the control plates were completely overgrown. The experiment was terminated after 9 days from inoculation. All tests were performed in triplicate, in two series.

The controls were fungal colonies growing on PDA supplied with solvent (DMSO) alone at the same concentrations of 0.1% and 1%. Plates were incubated at 27°C.

Coefficients of radial growth (T) and coefficients of linear growth inhibition (H) were calculated according to the equations below [20]:

$$T = \frac{A}{D} + \frac{b_1}{d_1} + \dots + \frac{b_x}{d_x}$$

where:

T – the coefficient of radial growth,

A – average diameter for colonies (mm),

D – number of days from the set-up of colonies to the final measurement,

b<sub>1</sub>, b<sub>x</sub> – the increment in colony diameter up to the final measurement (mm),

d<sub>1</sub>, d<sub>x</sub> – number of days from the final measurement.

Tab. 1 The effect of methanol extract from shoots of *Solanum nigrum* on segetal weeds.

Object	<i>Chenopodium album</i>			<i>Stellaria media</i>			<i>Papaver rhoeas</i>			<i>Viola arvensis</i>			<i>Thlaspi arvense</i>		
	F	Fresh weight (g)	Fresh weight reduction (%)	F	Fresh weight (g)	Fresh weight reduction (%)	F	Fresh weight (g)	Fresh weight reduction (%)	F	Fresh weight (g)	Fresh weight reduction (%)	F	Fresh weight (g)	Fresh weight reduction (%)
Control	1	13.1	100.0	1	11.7	100.0	1	13.4	100.0	1	12.8	100.0	1	10.8	100
40% extract from plants collected from the potato field	1	12.3	6.2	1-2 GI	11.3	3.5	2 GI	13.0	3.0	3 GI, CH	9.3	27.4	1	11.3	0
40% extract from plants collected from the maize field	1	12.6	3.9	1-2 GI	10.9	6.9	1-2 GI	12.9	3.8	2 GI	11.0	14.1	1	11.0	0
80% extract from plants collected from the potato field	3 GI	9.3	29.2	2 GI	11.2	4.3	2 GI	12.7	5.3	5 GI, CH, D	5.9	53.9	1	11.5	0
80% extract from plants collected from the maize field	1-2 GI	12.0	8.4	2 GI	11.4	2.6	1-2 GI	13.1	2.3	2 GI	10.9	14.9	1	11.2	0
LSD (0.05)		2.42		3.06			3.27			2.31			3.25		

F – phytotoxicity in scale 1–9 (scale explanation is given in “Material and methods”); GI – growth inhibition; CH – chlorosis; D – deformations.

The coefficient of linear growth inhibition (H) was calculated according to Abbot's equation [20] at the ninth day of the experiment:

$$H = \frac{K_0 - F}{K_0} \times 100\%$$

where:

H – the coefficient of linear growth inhibition,

K<sub>0</sub> – diameter of colonies on control plate,

F – diameter of colonies growing on dishes containing the extract at a particular concentration.

Statistical analysis was performed by analysis of variance at  $p \geq 0.05$  using Statistica 8.0 (StatSoft).

## Results

All the weed species tested are highly responsive to herbicides with different modes of actions, and, as such, have a rapid ability to adapt to various environments and preferences in this habitat. They also easily adapt to intensive agricultural management on arable lands.

Both the fractions extracted from shoots of *S. nigrum* collected from the potato fields were highly bioactive towards *V. arvensis* (Tab. 1). However, this species exhibited the strongest reaction to the 80% extract that was reflected in growth inhibition, leaf chlorosis, plant deformation, and consequently, biomass reduction. A similar plant response to the 80% extract obtained from *S. nigrum* from both the maize and potato fields was observed for *Ch. album*. The remaining weed species did not show any susceptibility to the extracts of *S. nigrum*, regardless of the origin of the plant material.

Considering the effect of all the extracts obtained from *A. fatua*, only the 80% extract prepared from the roots of plants collected from the spring wheat field showed high bioactivity for *Ch. album*, *S. media*, *V. arvensis*, and *P. rhoeas* (Tab. 2). The most susceptible to both the extracts were *Ch. album* and *S. media*, whereas *V. arvensis* was highly sensitive only to the 80% extract. The other weed species tested (*P. rhoeas*, *T. arvense*) did not show any susceptibility to the extract obtained from plants of *A. fatua*.

The results of this research allowed us to confirm the high bioactivity and inhibitory effect of the extracts obtained from both shoots and roots of *A. fatua* against three *Fusarium* species, i.e., *F. oxysporum*, *F. culmorum*, *F. avenaceum* (Tab. 3–Tab. 5). However, the root extract obtained from plants grown on the spring wheat field used at a concentration of 1% showed the greatest bioactivity. The coefficient of linear growth inhibition for *F. avenaceum* was as high as 72% (Tab. 5). The extract obtained from *A. fatua* was the only one which showed similar activity, but at a tenfold lower concentration (0.1%). The coefficients of linear growth inhibition for *F. oxysporum* and *F. culmorum* treated with both shoot and root extracts were 12% and 14%, respectively (Tab. 3, Tab. 4).

Tab. 2 The effect of methanol extract from roots of *Avena fatua* on segetal weeds.

Object	<i>Chenopodium album</i>			<i>Stellaria media</i>			<i>Papaver rhoeas</i>			<i>Viola arvensis</i>			<i>Thlaspi arvense</i>		
	F	Fresh weight (g)	Fresh weight reduction (%)	F	Fresh weight (g)	Fresh weight reduction (%)	F	Fresh weight (g)	Fresh weight reduction (%)	F	Fresh weight (g)	Fresh weight reduction (%)	F	Fresh weight (g)	Fresh weight reduction (%)
Control	1	12.8	100.0	1	11.2	100.0	1	13.1	100.0	100	11.9	100.0	100	11.7	100.0
40% extract from plants collected from the spring wheat field	2 GI	9.3	27.4	4 GI	7.3	34.9	1	12.3	6.2	1-2 GI	11.0	7.5	1-2 GI	11.3	3.5
40% extract from plants collected from the maize field	1-2 GI	11.0	14.1	1-2 GI	10.7	4.5	1	12.6	3.9	1-2 GI	10.7	10.1	1-2 GI	10.9	6.9
80% extract from plants collected from the spring wheat field	4 GI, D	5.9	53.9	6 GI, CH, N	4.2	62.5	3 GI	11.3	13.8	4 GI, D, CH	6.2	47.9	2 GI	11.2	4.3
80% extract from plants collected from the maize field	1-2 GI	10.9	14.9	2 GI	10.2	8.9	1-2 GI	12.0	8.4	5 GI, D, CH	5.8	51.3	2 GI	11.4	2.6
LSD (0.05)		3.42		3.11				3.26		3.31				3.19	

F – phytotoxicity in scale 1–9 (scale explanation is given in “Material and methods”); GI – growth inhibition; CH – chlorosis; D – deformations; N – necrosis.

## Discussion

Wild plants including segetal weeds exude different chemicals into their rhizosphere environments during their growth and at the time of their decomposition. These chemicals that possess bioactivity are allelochemicals as they influence germination, growth, development, and crop yield of other species [21]. During decomposition of plant residues resulting from tissue destruction, the allelochemicals exuded are quickly translocated into soil where decomposition is continued. Their bioactivity is therefore much affected by prevailing soil conditions, including pH and organic matter content. This was a reason for the investigation of individuals within species existing in different habitats [22,23]. The allelopathic potential of these compounds is higher in the early stages of plant growth and it decreases with ageing. For this reason, our study included individuals at different growth stages. The results we obtained confirm the greater phytotoxic effect for extracts obtained from young, aboveground parts of *S. nigrum*. Similar diversification in allelopathic potential was observed in laboratory and field experiments by other researchers [24,25]. They observed higher inhibitory effects of phenolics obtained from young aboveground parts of cereals and oil-seed rape as compared to those obtained from plants during the harvest period.

In a natural habitat, the species examined are the most frequent on humus-rich soil with a neutral pH [22]. Under field conditions, they prefer zero-tillage environments with an acidic soil that features an abundance of crop residues in the top layer of soil, and potentially uptake and accumulation of heavy metals derived from fertilizers and pesticides [2]. In this study, the plant material was collected from a maize field growing on brown soil with a neutral pH and high organic matter content, as well as from potato and spring wheat fields growing on podzolic soil with a slightly acidic pH and low organic matter content. The extracts obtained from both *S. nigrum* and *A. fatua* growing on podzolic soil resulted in a greater phytotoxic effect on the weed species examined.

Agroecosystems considerably alter the production of specific secondary metabolites, especially in plants that aggressively establish themselves in new habitats. The level of secondary metabolites in such plants is strongly affected by nitrogen availability in the soil. Plants growing in habitats poor in assimilable nitrogen produce compounds containing carbon sugars and other compounds not containing nitrogen, including terpenoids, phenolics, some pigments, and vitamins [26,27]. However, in intensively-managed arable habitats that are rich in assimilable nitrogen, plant metabolism is altered towards the production of nitrogen compounds such as free amino acids, proteins and alkaloids [14].

Plant metabolite production can be also affected by abiotic factors including temperature, water status, pesticides use, or heavy metal contamination. Our



**Tab. 3** The coefficient of radial growth (T) and the coefficient of linear growth inhibition (H) for *F. oxysporum* growing on PDA medium with addition of *S. nigrum* (maize field) and *A. fatua* (spring wheat field) extracts.

Plant part extracted	Plant extract concentration 1%			Plant extract concentration 0.1%		
	Colony diameter* (mm)	T	H (%)	Colony diameter* (mm)	T	H (%)
Control 1	81	87.3	-	84	91.8	-
<i>S. nigrum</i> – shoots	78	86.5	4	88	96.7	-5
<i>S. nigrum</i> – roots	80	86.3	1	81	92.4	4
Control 2	82	87.9	-	83	91.5	-
<i>A. fatua</i> – shoots	62	67.0	23	73	80.2	12
<i>A. fatua</i> – roots	45	48.5	44	71	79.0	14

The negative values means the stimulation of linear growth. \* Average colony diameter measured at the ninth day of the experiment.

**Tab. 4** The coefficient of radial growth (T) and the coefficient of linear growth inhibition (H) for *F. culmorum* growing on PDA medium with addition of *S. nigrum* (maize field) and *A. fatua* (spring wheat field) extracts.

Plant part extracted	Plant extract concentration 1%			Plant extract concentration 0.1%		
	Colony diameter* (mm)	T	H (%)	Colony diameter* (mm)	T	H (%)
Control 1	82	88.5	-	90	93.2	-
<i>S. nigrum</i> – shoots	83	89.2	-1	84	86.7	7
<i>S. nigrum</i> – roots	81	87.5	1	86	93.5	4
Control 2	81	87.1	-	85	89.8	-
<i>A. fatua</i> – shoots	43	47.1	47	75	81.8	12
<i>A. fatua</i> – roots	27	29.3	67	73	80.2	14

The negative values means the stimulation of linear growth. \* Average colony diameter measured at the ninth day of the experiment.

**Tab. 5** The coefficient of radial growth (T) and the coefficient of linear growth inhibition (H) for *F. avenaceum* growing on PDA medium with addition of *S. nigrum* (maize field) and *A. fatua* (spring wheat field) extracts.

Plant part extracted	Plant extract concentration 1%			Plant extract concentration 0.1%		
	Colony diameter* (mm)	T	H (%)	Colony diameter* (mm)	T	H (%)
Control 1	79	85.8	-	83	90.5	-
<i>S. nigrum</i> – shoots	81	88.3	-3	84	91.7	-1
<i>S. nigrum</i> – roots	83	90.2	-5	85	92.1	-2
Control 2	81	87.1	-	82	89.3	-
<i>A. fatua</i> – shoots	78	87.0	4	83	91.8	-1
<i>A. fatua</i> – roots	23	24.3	72	85	91.5	-4

The negative values means the stimulation of linear growth. \* Average colony diameter measured at the ninth day of the experiment.

literature review suggests that changes in metabolism of plant cells, tissues, or whole plants can be induced by addition some substances, such as dichlorophenoxyacetic acid (2,4-D), 6-benzilaminopurine (6-BAP), kinetin,  $\alpha$ -naphthylacetic acid (NAA), indolyl-3-acetic acid (IAA), methyl jasmonate, or even by UV-B radiation [15,16,21].

Plants exposed to environmental stresses or infested by pathogens produce chemical defences such as preinfection compounds. However, these substances are constantly present in the plant regardless of whether the plant is infected or not. This group includes the metabolites which limit or totally inhibit growth of microorganisms and also the metabolites whose concentration increases after infection, e.g., terpenoids, quinones, and phenolics [28,29]. The other metabolite group involved in resistance to pathogenic fungi is the hydroxystilbenes. This includes five-cyclic triterpenic glycosides represented by avenacin A1 extracted from oats. It has shown a moderate inhibitory effect against the fungus *Candida albicans* [30–33]. This finding was partly confirmed in the present research, in which the growth inhibition for *F. oxysporum*, *F. culmorum*, and some of the weed species treated with the root extract obtained from *A. fatua* was proven.

Bioactive compounds extracted from plants belonging to the genus *Solanum* can be also used in the pharmaceutical industry. One example is the alkaloid solasodine, which is extracted from these plants. Another reported in the literature is important pharmaceutically, the sapogenin steroid diosgenin. It occurs in plants of the Dioscoreaceae family and also in some species in the Solanaceae and Fabaceae. The presence of tigogenin, diosgenin and yamogenin has been noted in *S. dulcamara* [9]. However, *S. nigrum* is highly toxic because of the glycoalkaloids content (solanine, solamargine, solasonine) in fruits [18]. In some European countries, solasonine is used as starting material for half-synthesis of corticosteroids and sex hormones, and it also exhibits traits similar to cortisone [34,35]. Solanine, solamargine, and the plant extract obtained from *S. nigrum* at a concentration of  $10^{-5}$  M induced a negative chronotropic effect on the activity of the shrinkage heart beetle *T. molitor*. Among these substances, the strongest activity has been shown by solasonine. Some studies have also reported highly cytostatic effects of this compound [36,37].

Environmental conditions on arable fields affect both seed germination and plant morphological traits, as well as determine the concentration of bioactive compounds, enzymatic activity, and rates of plant decomposition [16,17,38]. Many plant species infected by microorganisms start to accumulate metabolites to reach a toxic level. They are mainly aromatic compounds and especially coumarin derivatives. Coumarins and phenolic acids are highly toxic to numerous microorganisms. As an example, scopolamine and chlorogenic acid are phenolic compounds that are accumulated in plants belonging to the Solanaceae due to their infection by the fungus *Phytophthora infestans*. Phenolic acids are also recognized as substances able to inhibit seed germination [10].

The results of our studies on the effects of plant extracts obtained from commonly occurring weed species and invasive plants encourage investigation in this area. Further research can be useful in the development new plant protection products that are pro-ecological and neutral to the natural environment.

## Conclusions

- The most sensitive weed species to the extracts tested was *V. arvensis*. Its growth was significantly reduced when plants were treated with 80% methanol extracts of *S. nigrum*. A similar reaction to the 80% methanol extract was recorded for *Ch. album*.
- Methanol extracts at concentrations of 40% and 80% obtained from *A. sativa* roots growing on a spring wheat field caused growth inhibition, plant injuries (chlorosis, deformation), and significant biomass reduction of *Ch. album* and *S. media*. A similar response was observed for *V. arvensis* treated with this extract at a concentration of 80%.
- The addition of methanol extracts from *A. fatua* to PDA medium at a concentration of 1% and also as low as 0.1% caused significant growth inhibition of *F. avenaceum*, *F. culmorum*, and *F. oxysporum* mycelium.
- The extract from *S. nigrum* at a concentration of 1% slightly stimulated the growth of *F. oxysporum* mycelium.

## References

1. Balcerkiewicz S, Pawlak G. Rośliny lecznicze w zbiorowiskach segetalnych Polski. Pamiętnik Puławski. 2003;134:65–77.
2. Kaczmarek S. Wykorzystanie potencjału allelopatycznego roślin w wybranych uprawach rolniczych. Progress in Plant Protection. 2009;4(3):1502–1511.
3. Kączkowski J. Biochemia roślin. Tom I. Przemiany typowe. 5th ed. Warszawa: Państwowe Wydawnictwo Naukowe; 1992.
4. Kączkowski J. Biochemia roślin. Tom II. Metabolizm wtórny. 2nd ed. Warszawa: Państwowe Wydawnictwo Naukowe; 1993.
5. Marshall EJP, Brown VK, Boatman ND, Lutman PJW, Squire GR, Ward LK. The role of weeds in supporting biological diversity within crop fields. Weed Res. 2003;43(2):77–89. <https://doi.org/10.1046/j.1365-3180.2003.00326.x>
6. Kazimierzczak R, Hallmann E, Zduńska U, Rembiałkowska E. Zawartość przeciwutleniaczy w ziołach przyprawowych pochodzących z produkcji ekologicznej i konwencjonalnej. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Poznaniu. 2010;55(3):164–170.
7. Corbiere C, Liagre B, Bianchi A, Bordji K, Dauca M, Netter P, et al. Different contribution of apoptosis to the antiproliferative effects of diosgenin and other plant steroids, hecogenin and tigogenin, on human 1547 osteosarcoma cells. Int J Oncol. 2003;22(4):899–905. <https://doi.org/10.3892/ijo.22.4.899>
8. Corbiere C, Liagre B, Terro F, Beneytout JL. Induction of antiproliferative effect by diosgenin through activation of p53, release of apoptoso-inducing factor (AIF) and modulation of caspase-3 activity in different human cancer cells. Cell Res. 2004;14(3):188–196. <https://doi.org/10.1038/sj.cr.7290219>
9. Lamer-Zarawska E, Kowal-Gierczak B, Niedworok J. Fitoterapia i leki roślinne. Warszawa: Wydawnictwo Lekarskie PZWL; 2007.
10. Moglad EHO, Abdalla OM, Koko WS, Saadabi AM. In vitro anticancer activity and cytotoxicity of *Solanum nigrum* on cancers and normal cell lines. Int J Cancer Res. 2014;10:74–80. <https://doi.org/10.3923/ijcr.2014.74.80>
11. Oleszek W. Funkcja ekologiczna saponin. In: Oleszek W, Głowniak K, Leszczyński B, editors. Biochemiczne oddziaływania środowiska. Lublin: Wyd. AM; 2001. p. 213–229.
12. Stokłosa A. Bioherbicydy i alleloherbicydy w walce z chwastami. Postępy Nauk Rolniczych. 2006;6:41–52.
13. Kacperska A, Kopcewicz J, Lewak S, Gabryś H. Fizjologia roślin. Warszawa: Wydawnictwo Naukowe PWN; 2002.
14. Brandt K, Mølgaard JP. Organic agriculture: does it enhance or reduce the nutritional value of plants foods? J Sci Food Agric. 2001;18:924–931. <https://doi.org/10.1002/jsfa.903>
15. Antognoni F, Zheng S, Pagnucco C, Baraldi R, Poli F, Biondi S. Induction of flavonoid production by UV-B radiation in *Passiflora quadrangularis* callus cultures. Fitoterapia. 2007;78:345–352. <https://doi.org/10.1016/j.fitote.2007.02.001>
16. Boltenkov EV, Rybin VG, Zarembo EV. Flavones from callus tissue of *Iris ensata*. Chem Nat Compd. 2005;41(5):539–541. <https://doi.org/10.1007/s10600-005-0200-1>
17. Milovanović V, Radulović N, Todorović Z, Stojanović G. Antioxidant, antimicrobial and genotoxicity screening of hydro-alkoholic extracts of five Serbian *Equisetum* species. Plant Foods Hum Nutr. 2007;62:113–119. <https://doi.org/10.1007/s11130-007-0050-z>
18. Zhou X, He X, Wang G, Gao H, Zhou G, Ye W, et al. Steroidal saponins from *Solanum nigrum*. J Nat Prod. 2006;69(8):1158–1163. <https://doi.org/10.1021/np060091z>
19. Niekerk BD, Pretorius ZA, Boshoff WHP. Pathogenic variability of *Puccinia coronata* f. sp. *avenae* and *Puccinia graminis* f. sp. *avenae* on oat in South Africa. Plant Dis. 2001;85(10):1085–1090. <https://doi.org/10.1094/pdis.2001.85.10.1085>
20. Kowalik R, Krechniak E. Szczegółowa metodyka biologicznych i laboratoryjnych badań środków grzybobójczych. In: Materiały do metodyki badań biologicznej oceny środków ochrony roślin. Poznań: IOR; 1961. p. 35–48.
21. Bołonkowska O, Pietrosiuk A, Sykłowska-Baranek K. Roślinne związki barwne, ich właściwości biologiczne oraz możliwości wytwarzania w kulturach in vitro. Biuletyn Wydziału Farmaceutycznego Warszawskiego Uniwersytetu Medycznego. 2011;1:1–27.
22. Gawroński SW. Allelopathic precrop mulch as a tool of weeds managements in winter wheat organic farming. In: Proceedings on the 2th European Allelopathy Symposium.



- Puławy: Institute of Soil Science and Plant Cultivation; 2004. p. 26.
23. Wesołowski M, Jędruszczak M, Cierpiąła R. Organizacja zbiorowiska chwastów w zależności od systemu uprawy dwóch odmian pszenicy ozimej. *Acta Agrophysica*. 2003;1:787–793.
  24. Schubert P, Waldhardt R, Otte A. Der Einfluss unterschiedlicher Nutzungsgeschichte auf die Fitness von *Viola arvensis* Murr. *Nova Acta Leopold*. 2003;87:389–394.
  25. Kryzevicienė A, Paplauskienė V. Estimation of allelopathic potential of perennial grasses. *Zeszyty Problemowe Postępów Nauk Rolniczych*. 2004;496:331–341.
  26. Wu H, Pratley J, Lemerle D, An M, Liu DL. Autotoxicity of wheat (*Triticum aestivum* L.) as determined by laboratory bioassays. *Plant Soil*. 2007;296:85–93. <https://doi.org/10.1007/s11104-007-9292-7>
  27. Gould KS, Lister C. Flavonoid functions in plants. In: Andersen ØM, Markham KR, editors. *Flavonoids: chemistry, biochemistry, and applications*. Boca Raton, FL: CRC Press; 2006. p. 397–443.
  28. Dhellot JR, Matouba E, Maloumbi MG, Nzikou JM, Dzondo MG. Extraction and nutritional properties of *Solanum nigrum* L. seed oil. *Afr J Biotechnol*. 2006;5:987–991.
  29. Uematsu Y, Hirata K, Saito K. Spectrophotometric determination of saponin in *Yucca* extract used as food additive. *J AOAC Int*. 2000;83:1451–1454.
  30. Piotrowski W, Sas-Piotrowska B, Wyrostkiewicz K, Czajkowski P. Wpływ wyciągów roślinnych na kiełkowanie zarodników niektórych gatunków grzybów patogenicznych dla roślin. *Zeszyty Naukowe Akademii Techniczno-Rolniczej w Bydgoszczy, Rolnictwo*. 1995;190(36):139–145.
  31. Majchrzak L. Kiełkowanie zbóż w warunkach sąsiedztwa ziarniaków *Avena fatua* L. i *Festuca rubra* L. – aspekt allelopatyczny. *Annales Universitatis Mariae Curie-Skłodowska, Sectio E, Agricultura*. 2007;62(2):185–192.
  32. Iannucci A, Fragasso M, Platani C, Papa R. Plant growth and phenolic compounds in the rhizosphere soil of wild oat (*Avena fatua* L.). *Front Plant Sci*. 2013;4:509. <https://doi.org/10.3389/fpls.2013.00509>
  33. Amoghein MB, Amoghein RS, Tobeh A, Jamaati-e-Somarin S. Allelopathic effects of extracts and plant residues of wild oat (*Avena fatua*) and rye (*Secale cereale* L.) on some germination parameters of wheat crop (*Triticum aestivum*) in the greenhouse condition. *International Research Journal of Applied and Basic Sciences*. 2009;4(8):2313–2321.
  34. Oleszek WA. Chromatographic determination of plant saponins. *J Chromatogr A*. 2000;967:147–162. [https://doi.org/10.1016/S0021-9673\(01\)01556-4](https://doi.org/10.1016/S0021-9673(01)01556-4)
  35. Kohlmünzer S. *Farmakognozja: podręcznik dla studentów farmacji*. 5 ed. Warszawa: Wydawnictwo Lekarskie PZWL; 2003, p. 669.
  36. Ventrella E, Marciniak P, Adamski Z, Rosiński G, Chowański S, Falabella P, et al. Cardioactive properties of Solanaceae plant extracts and pure glycoalkaloids on *Zophobas atratus*. *Insect Sci*. 2015;22:251–262. <https://doi.org/10.1111/1744-7917.12110>
  37. Al-Qirim T, Zaidi SM, Shahwan M, Shattat G, Banu N. Effect of *Solanum nigrum* on immobilization stress induced antioxidant defence changes in rat. *Research Journal of Biological Sciences*. 2008;3:1426–1429.
  38. Schreiner M. Vegetable crop management strategies to increase the quantity of phytochemicals. *Eur J Nutr*. 2005;44:85–94. <https://doi.org/10.1007/s00394-004-0498-7>

### **Oddziaływanie ekstraktów roślinnych *Solanum nigrum* L. i *Avena fatua* L. na wzrost i rozwój agrofagów**

#### **Streszczenie**

W warunkach szklarniowych przeprowadzono testy biologiczne z wykorzystaniem 40% i 80% frakcji metanolowych sporządzonych z części nadziemnych psianki czarnej (*Solanum nigrum* L.) oraz z części podziemnych owsa głuchego (*Avena fatua* L.). Ekstrakty przygotowano na bazie roślin zebranych z różnych pól uprawnych. Celem badań było wykazanie różnic w oddziaływaniu tych frakcji na wzrost i rozwój niektórych agrofagów (*Viola arvensis* Murr., *Chenopodium album* L., *Stelaria media* L., *Papaver rhoeas* L., *Thlaspi arvense* L.) oraz grzybów patogenicznych [*Fusarium avenaceum* (Fr.) Sacc, *F. culmorum* (W. G. Sm.), *F. oxysporum* Schlecht.]. Zaobserwowano zmiany morfologiczne roślin i istotną obniżkę świeżej masy *V. arvensis* potraktowanych ekstraktami 40% i 80% frakcji metanolowych. Podobną istotną reakcją wykazała *Ch. album*, ale jedynie po aplikacji 80% frakcji metanolowej *S. nigrum* pochodzącej z uprawy kukurydzy. Najbardziej wrażliwymi

gatunkami na obie frakcje metanolowe z części podziemnych *A. fatua* pochodzącego z uprawy pszenicy jarej okazały się *Ch. album* i *S. media*, natomiast *V. arvensis* był wrażliwy tylko na 80% frakcję metanolową. Stwierdzono również, że dodatek wyciągów metanolowych z *A. fatua* do pożywki PDA zarówno w stężeniu 1% jak i w stężeniu 0,1% powodował znaczące zahamowanie wzrostu grzybni *Fusarium avenaceum* (Fr.) Sacc, *F. culmorum* (W. G. Sm.) oraz *F. oxysporum* Schlecht i *F. avenaceum* (Fr.) Sacc. Natomiast dodatek wyciągów metanolowych z *S. nigrum* do pożywki PDA w stężeniu 1% tylko w niewielkim stopniu stymulował wzrost grzybni patogena *F. oxysporum* Schlecht.