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FROM BIOSTIMULANT TO POSSIBLE PLANT BIOPROTECTANT AGENTS

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ABSTRACT

Aqueous extracts of plants with proven biostimulant activity may have the potential to inhibit the growth and development of plant disease-causing fungi. The potential use of extracts in such a role has many advantages including the fact that extracts are biodegradable, less costly, and readily available. Therefore, the aim of this study was to evaluate the potential of aqueous infusions, decoctions, and macerates extracted from burdock roots, wormwood leaves, lovage roots, flax seeds, and mullein flowers as bioprotectants. This study was carried out by testing *in vitro* the ability of these bioprotectants to inhibit the growth of the fungi *Thielaviopsis basicola* (Berk. and Broome), and *Fusarium avenaceum* (Fr.) Sacc, *Fusarium culmorum* (Wm.G. Sm.) Sacc., *Fusarium sambucinum* (Fuckel), *Fusarium solani* (Mart.) Sacc., *Rhizoctonia solani* (J.G. Kühn), *Botrytis cinerea* Pers., *Sclerotinia sclerotiorum* (Lib. de Bary), causing disease in soybean. The antifungal activity of macerates, infusions, and decoctions determined by the diffusion method in Petri dishes with solid PDA medium showed the potential of the tested aqueous extracts as bioprotectants able to inhibit the growth of fungi, causing soybean diseases.

Introduction

Soybean (*Glycine max* L. Merrill), belonging to the Fabaceae family, is a crop with a high economic and nutritional value (Yang et al., 2019). Nowadays, this crop has become one of the most important in agriculture due to its protein and lipid content which has consequently made it play an important role in global food security (Li et al., 2010; Feng et al., 2021). However, the problem with soybean cultivation is that it is vulnerable to the pathogen attack. Up to about forty diseases, caused by fungi, bacteria, nematodes, and viruses can occur in areas where soybean is grown. As the global cultivation of soybean continues to increase, it is important to emphasize that monoculture has caused an increase in diseases, leading to lower yields of this crop(de Almeida Lopes et al., 2018). Yield losses caused by pathogen pressure often make control essential. However, common control practice is based on the use of agrochemicals. Although synthetic plant protection products are considered effective, they

are not indifferent to the environment (Onunkun, 2012). Indeed, they can negatively affect the agricultural ecosystem and increase the evolutionary resistance of pathogens (Stevenson and Belmain, 2016; Kayange et al., 2019). Nowadays, in order to achieve sustainable and environmentally friendly agricultural systems, great importance is placed on the search for methods that would reduce the use of synthetic fertilizers and pesticides. Bioprotectants, defined as substances derived from natural sources, whose action is associated with the prevention of pathogen attacks on agricultural plants, have gained recognition in this regard. This action is often attributed to toxic and inhibitory mechanisms (Lengai et al., 2020; Hikal et al., 2017, Kisiriko et al., 2021).

Many plant species are described as medicinal. These plants are sources of many bioactive compounds, thus possessing a great pharmaceutical potential (Begum et al., 2016; Sasidharan et al., 2012; Hayat et al., 2022). However, recent studies indicate that the biological activity of extracts from medicinal or aromatic plants is of great importance for agriculture. Indeed, extracts may exhibit biostimulatory potential, i.e., when applied to crop plants, they increase nutrient uptake, stress tolerance and/or improve yield quality traits (Habtemariam, 2019; Putnik et al., 2018; Khalimi et al., 2022). The biostimulant effects of phytoextracts are attributed to the secondary metabolites they contain, primarily phenolic compounds, alkaloids, and terpenes and terpenoids (Jain et al., 2019; Takshak and Agrawal, 2019; Kisiriko et al., 2021). Among medicinal and aromatic plants, aqueous extracts from *Arctium lappa* L.*, Artemisia absinthium* L.*, Levisticum officinale* L.*, Linum usitatissimum* L.,and *Verbascum thapsiforme* Schrad. They have been qualified as natural biostimulants in soybean cultivation (patent applications P.434975; P.434976; P.434977; P.434978; P.434979). However, the bioprotective potential of these extracts has not been investigated so far. Indeed, the demonstrated biostimulant potential does not exclude a bioprotective effect. Currently, the use of extracts in such a role has many advantages including the fact that extracts are biodegradable (Onunkun, 2012), less costly, and readily available (Egho and Emosairue, 2010; Kayange et al., 2019). The evaluation of the potential use of medicinal and aromatic plant extracts as bioprotectants is related to their potential antimicrobial and antifungal or anti-insect activities against pathogens and pests in crops (Kisiriko et al., 2021; Jyotsna et al., 2017). Simple phenols, phenolic acids, flavonols, and dihydrochalcones as well as many flavones and flavanones show activity against fungal pathogens of crop plants including Aspergillus sp., *Botrytis cinerea* and *Fusariumoxysporum* (Weidenbörner et al., 1990; Lattanzio et al., 2006). Some plant pathogens, including *Botrytis fabae*, have been naturally controlled by the use of phytoextracts (Roman, 2010; Tegegn et al., 2016). Previous studies have shown that aqueous extracts extracted from *Arctium lappa* L., *Artemisia absinthium* L., *Levisticum officinale* L., *Linum usitatissimum* L., and *Verbascum thapsiforme* Schrad, significantly reduced fungal and bacterial contamination of seeds of white mustard, white cabbage, yellow lupine, pea, fodder beet, sugar beet, and red beet, winter oilseed rape, winter turnip, as well as spring barley seeds (Kocira et al., 2020; Kocira et al., 2018; Szparaga et al., 2017; Czerwińska et al., 2015; Czerwińska and Szparaga, 2015a). Thus, the observed positive responses of crop seeds and grains to phytoextracts have prompted studies on the evaluation of the bioprotective activity of extracts with proven biostimulatory effects. Such an approach may enable the wider use of organic extracts in agricultural crops. The aim of this work was to investigate the potential of aqueous infusions, decoctions, and macerates extracted from burdock roots, wormwood leaves, lovage roots, flax seeds, and mullein flowers as bioprotectants. This study was carried out by testing *in vitro* their ability to inhibit the growth of the fungi *Thielaviopsis*

basicola (Berk. and Broome), *Fusarium avenaceum* (Fr.) Sacc., *Fusarium culmorum* (Wm.G. Sm.) Sacc, *Fusarium sambucinum* (Fuckel), *Fusarium solani* (Mart.) Sacc., *Rhizoctonia solani* (J.G. Kühn), *Botrytis cinerea* Pers., *Sclerotinia sclerotiorum* (Lib. de Bary), causing diseases of soybean.

Material and methods

Plants for the production of extracts

Dried roots of burdock (*Arctium lappa* L.), leaves of wormwood (*Artemisia absinthium* L.), roots of lovage (*Levisticum officinale* L.), seeds of flax (*Linum usitatissimum* L.) and flowers of mullein (*Verbascum thapsiforme* Schrad.) were used to produce the extracts. The plants were organically grown (Runo, PL-EKO-07-04901 EU Organic Farming). To make the extracts, the corresponding morphological parts of the dried plants were ground to a fraction size of 500 μm.

Cold water extraction (CWE) - macerates

Macerates were prepared by adding 100 mL of distilled water to 5 g of ground plants. The solution was left in a dark place for 48 h at 8°C. The macerates were then centrifuged at 4250 rpm for 5 min and filtered through Whatman No. 1 filter paper (Sas-Piotrowska et al., 2004).

Hot water extraction (HWE)-infusions

Plant infusions were prepared by hot water extraction. 5g of crushed plants were added to 250 mL of distilled water and the resulting suspension was maintained at 100°C in a water bath for 30 minutes. The infusions were then centrifuged at 4250 rpm for 5 minutes and filtered through Whatman No. 1 filter paper (Sas-Piotrowska et al., 2004).

Water-based preparation to extract - decoctions

The decoction was prepared by pouring 8.75 g of dried plants into 1000 mL of distilled water. The resulting suspension was stirred thoroughly and then allowed to stand for 24 hours at 20°C ±0.5°C. After this time, the solution was kept boiling for 15 minutes (Tyszyńska-Kownacka and Starek, 1989). The decoctions were then centrifuged at 4250 rpm for 5 minutes and filtered through Whatman No. 1 filter paper.

Fungal strains

All fungal strains were obtained from the collection of phytopathogenic fungi maintained at the Department of Plant Diseases and Pathogen Bank, Institute of Plant Protection - National Research Institute, Poznań, Poland. Strains of *Thielaviopsis basicola* (Berk. and Broome), *Fusarium avenaceum* (Fr.) Sacc., *Fusarium culmorum* (Wm.G. Sm.) Sacc., *Fusarium sambucinum* (Fuckel), *Fusarium solani* (Mart.) Sacc., *Rhizoctonia solani* (J.G. Kühn), *Botrytis cinerea* (Pers.), and *Sclerotinia sclerotiorum* (Lib. de Bary) were originally isolated from infected soybean.

Inoculum preparation

The fungal inoculum was prepared from a 5-day-old culture grown on potato dextrose agar medium. Petri dishes were flooded with 8-10 mL of distilled water and conidia were scraped with a sterile spatula. The spore density of each fungus was adjusted using a spectrophotometer (at 595 nm) to obtain a final concentration of approximately 10^5 spores/mL (Mahesh and Satish, 2008).

Antifungal activity

The antifungal activity of macerates, infusions, and decoctions was determined by the diffusion method in Petri dishes (ø10 cm) with solid PDA medium (Potato Dextrose Agar - Pol-Aura, Poland). Four drops of an aqueous suspension of spores and mycelial fragments were applied to each substrate, then spread evenly over the surface, dried and placed on a paper disc (ø6 mm) soaked in the botanical extract. The measure of the activity of the extracts was the size of the zone of inhibition of colony growth (in millimeters) measured after 5 days of incubation at 22°C. The experiment was set up in six replicates for each plant, extract preparation method, and pathogen. Each repetition consisted of four Petri dishes (Czerwińska and Szparaga, 2015b).

Statistical analysis

Results were statistically analyzed by analysis of variance with single classification (P = 95%), separately for each plant, preparation method, and individual pathogen. Fisher's least significant difference test ($LSD_{0.05}$) was used to test for differences between samples at the 5% significance level. Statistical analysis was performed using the ANW program (Analysis of Variance of Experiments, Bydgoszcz, Poland).

Results and discussion

The study showed that the response of the tested fungi depended on the plant species from which the extract was prepared and the method of preparation (Table 1). First- and second-order interactions were also statistically significant. The results obtained are consistent with those presented in the literature, indicating that extracts from many plants (including medicinal plants) are effective antimicrobial agents. Jasim et al. (2013) and Hayat et al. (2022) demonstrated that extracts from garlic, ginger or fenugreek exhibit potent antifungal properties against Candida spp,. On the other hand, a study by Ambikapathy and Gomathi (2011) showed an antifungal activity of *Lawsonia inermis* L., *Mimosa pudica* L., *Phyllanthus niruri* L., *Tephrosia purpurea* Pens., *Vinca rosea* L. against the plant pathogenic fungi *Pythium debaryanum*. Thus, this demonstrates the bioprotective potential of extracts from many plants. This is mainly due to the presence of multiple antimicrobial compounds in different morphological parts of the plants, whereby the extracts can offer an adequate range of protection to crop plants against a wide range of diseases (Kumar et al., 2017; Kavita, 2013; Tudu et al., 2021).

Table 1.
Antifungal activity of plant extracts in disc-diffusion method, inhibition zones (mm)

Tested fungi	Plant extracts														
	Linum usitatissimum			*Levisticum officinale*			*Verbascum thapsiforme*			*Artemisia absinthium*			*Arctium lappa*		
	macerate	infusion	decoction	macerate	infusion	decoction	macerate	infusion	decoction	macerate	infusion	decoction	macerate	infusion	decoction
Thielaviopsisbasicola	5.67 ±0.24	9.50 ±0.41	7.00 ±0.41	6.83 ±0.24	10.00 ±0.40	7.17 ±0.23	6.00 ±0.40	8.00 ±0.28	7.83 ±0.23	6.33 ±0.24	8.33 ±0.13	12.00 ±0.40	9.33 ±0.23	12.00 ±0.40	12.33 ±0.13
Fusarium solani	6.33 ±0.23	8.13 ±0.12	6.20 ±0.13	7.10 ±0.12	10.17 ±0.16	8.30 ±0.28	8.03 ±0.13	8.17 ±0.31	8.07 ±0.04	7.20 ±0.16	8.00 ±0.16	7.47 ±0.37	6.20 ±0.13	7.10 ±0.08	6.90 ±0.08
Botrytis cinerea	13.97 ±0.21	9.10 ±0.29	14.90 ±0.29	9.00 ±0.08	13.83 ±0.23	13.97 ±0.20	9.13 ±0.12	8.13 ±0.26	9.00 ±0.16	7.23 ±0.26	9.20 ±016	8.16 ±0.24	7.20 ±0.16	8.07 ±0.17	9.10 ±0.37
Fusarium avenaceum	7.17 ±0.24	8.20 ±0.16	6.23 ±0.21	7.97 ±0.26	7.37 ±0.27	9.23 ±0.20	7.13 ±0.12	7.27 ±0.20	7.00 ±0.08	8.10 ±0.08	7.93 ±0.09	7.23 ±0.17	8.37 ±0.28	8.23 ±0.26	7.90 ±0.08
Rhizoctonia solani	8.20 ±0.22	10.20 ±0.21	10.20 ±0.16	8.20 ±0.21	8.03 ±0.13	9.00 ±0.16	12.00 ±0.08	8.23 ±0.26	13.93 ±0.17	7.93 ±0.13	12.13 ±0.12	8.03 ±0.05	7.90 ±0.08	7.80 ±0.14	8.93 ±0.17
Fusarium culmorum	7.90 ±0.14	5.97 ±0.12	6.00 ±0.41	5.97 ±0.12	7.07 ±0.17	6.07 ±0.25	7.10 ±0.08	6.17 ±0.24	5.87 ±0.09	7.10 ±0.08	7.07 ±0.17	8.20 ±0.22	6.10 ±0.08	7.33 ±0.23	6.03 ±0.05
Fusarium sambucinum	6.83 ±0.31	8.23 ±0.21	8.20 ±0.28	7.27 ±0.25	7.03 ±0.05	6.30 ±0.22	7.17 ±0.24	6.90 ±0.08	7.10 ±0.08	7.03 ±0.05	6.90 ±0.08	6.83 ±0.12	7.17 ±0.17	6.23 ±0.16	6.20 ±0.21
Sclerotinia sclerotiorum	9.43 ±0.31	10.37 ±0.26	10.37 ±0.29	6.10 ±0.08	8.87 ±0.12	10.10 ±0.08	8.23 ±0.26	11.40 ±0.29	12.27 ±0.25	8.37 ±0.29	7.80 ±0.22	8.20 ±0.21	7.27 ±0.25	7.17 ±0.17	6.90 ±0.08
Least significant difference $LSD_{0.05}$	$LSD_{\text{type of extract}} = 0.09$ $LSD_{\text{method of obtaining the extract}} = 0.07$ $LSD_{\text{species of fungi}} = 0.11$						$LSD_{\text{type of extract x method of obtaining the extract}} = 0.15$ $LSD_{\text{type of extract x species of fungi}} = 0.25$ $LSD_{\text{method of obtaining the extract x species of fungi}} = 0.19$ $LSD_{\text{type of extract x method of obtaining the extract x species of fungi}} = 0.32$								

The data show the diameter of inhibition zone growth in mm. LSD - the least significant difference. When significant ($p<0.05$), the value of LSD is indicated.

The pathogen growth was most strongly inhibited by extracts from *Linum usitatissimum* (mean zone ø8.47 mm), and the fungus *Botrytis cinerea* showed the greatest sensitivity to this extract (mean zone ø12.66 mm). At the same time, the application of aqueous extracts (macerate, infusion, decoction) of *Levisticum officinale* significantly inhibited the growth of the microorganisms (mean zone ø8.37 mm). In this case, the greatest zones of growth inhibition were also recorded for the fungus *Botrytis cinerea*. The study showed that the fungi tested showed the least sensitivity to *Arctium lappa* extracts .

The fungal growth on PDA medium (Table 1) was most strongly inhibited by decoctions and infusions (ø 8.49 mm and 8.41 mm). According to Sas-Piotrowska and Piotrowski (2003), changes in the antifungal activity and thus the biological activity of different forms of plant extracts can be attributed to several factors, most importantly the content of specific chemical compounds and their ability to diffuse depending on the extraction method used. The differences between the effects of the infusion, macerate, and decoction may have been

due to the different solubility of the extracted compounds in an aqueous medium and the temperature of the extraction processes.

Among the fungi analyzed, the most sensitive to the extracts used were: *Botrytis cinerea* (mean zone of inhibition ø10.00 mm) and *Rhizoctonia solani* (ø9.38 mm). Fungi resistant to the use of plant extracts were: *Fusarium culmorum* and *Fusarium sambucinum* (mean zone of inhibition ø6.66 mm and 7.03 mm). Similar conclusions were reached by Ibrahim and Al-Naser (2014), whose study of the effect of *S. molle* fruit extracts showed that the greatest inhibition effect was for the fungus *Botrytis cinerea*. The researchers attributed this effect to the terpenoids (monoterpenes and sesquiterpenes) present in the extracts, to which *Botrytis cinerea* fungi are sensitive (Tegegn et al., 2016).

Extracts from *Linum usitatissimum* were most potent in reducing the growth of the fungus *Botrytis cinerea* when prepared as macerates and decoctions (ø14.90 and 13.97 mm). In contrast, their effect on the fungus *Sclerotinia sclerotiorum* was greatest when flax seed extracts were obtained by hot extraction (ø10.37 mm). Similar relationships were recorded for *Rhizoctonia solani*. A study by Guilloux et al. (2009) found that extracts and oils from *L. usitatissimum* exhibited antifungal activity against *Candida albicans, Alternia solani, Alternia alternata, Penicillium chrysogenum,*and *Fusarium graminearum*. In addition, Xu et al. (2008) demonstrated that flaxseed extracts were also characterized by fungistatic activity against the fungi *Fusarium graminearum*, *Penicillium chrysogenum,* and *Aspergillus flavus*. According to Fadzir et al. (2018), the antifungal potential of *Linum usitatissimum* extracts may be a result of the fatty acids (including α-linolenic and linoleic acids) they contain. This is supported by a study by Abdelillah et al. (2013), which identifies flax extracts as effective in the treatment of fungal infections.

Analysis of the effects of *Levisticum officinale* extracts showed that they exhibited inhibitory abilities against the fungi *Botrytis cinerea* (ø 13.83 mm), *Fusarium solani* (ø 10.17 mm) and *Thielaviopsis basicola* (ø 10.00 mm), when aqueous infusions were used for testing. An earlier study by Samiee et al. (2006) confirmed the antimicrobial activity of lovage extracts. The researchers attributed this activity, to the monoterpene compounds contained in the extracts, which play a role in the destruction of cellular biomembranes. Such degrading activity has been demonstrated against *P. aeruginosa*, *Acinetobacter baumannie, Escherichia coli,*and *Salmonella enteritidis* (Ebrahimi et al., 2017).

Extracts produced from *Verbascum thapsiforme* flowers were most effective in reduction of the growth of *Sclerotinia sclerotiorum* in the form of infusions (ø11.40 mm) and decoctions (ø12.27 mm). Studies by Magiatis et al. (2001) and Turker and Gurel (2005) demonstrated the antimicrobial potential of aqueous extracts of many mullein species, which showed antibacterial activity against *Klebsiella pneumonia, Staphylococcus aureus, S. epidermidis,*and *Escherichia coli*. In contrast, a study by Kahraman et al. (2011) indicated the antifungal potential of the extracts against *Candida albicans, C. parapsilosis,*and *C. krusi* fungal strains (Alipieva et al., 2014).

Inhibition of the growth of the fungus *Thielaviopsis basicola* was significantly greater when decoctions of *Artemisia absinthium* were used (ø 12.00 mm). In contrast, the greatest zone of inhibition of *Sclerotinia sclerotiorum* fungal growth was recorded as a result of testing macerates from this plant (ø8.37 mm). Studies on the oils, extracted from *Artemisia absinthium*, confirmed the antifungal effect of the biologically active compounds contained therein. Wormwood extracts showed significant inhibitory activity against *F. graminearum,*

F. culmorum and *F. oxysporum*, and slightly less against *Sclerotinia sclerotiorum* and *Rhizoctonia solani*. According to Bozin et al. (2008), the antifungal effect may be related to the chamazulene contained in the extract. In addition, mugwort extracts contain (Z)-epoxyocimen and chrysanthenyl acetate in their composition. These compounds have been shown to inhibit the growth of *Candida albicans* and *Saccharomyces cerevisiae* (Juteau et al. 2003). The essential oil itself, extracted from *Artemisia absinthium*, shows fungicidal activity against more than 30 species of fungi of the genus Fusarium, including, among others, *F. solani* and *F. oxysporum*, and against *Alternaria* sp. and *Botrytis cinerea* (Umpiérrez et al., 2012).

The impact of extracts produced from *Arctium lappa* was significantly greatest when infusions and decoctions of this plant were tested (ø12.00 and 12.33 mm). The results obtained therefore indicate the antifungal potential of extracts from this plant. Previous studies conducted on ethanolic extracts of *Arctium lappa* have shown that they exhibit an antimicrobial activity against a range of bacteria, including *P. aeruginosa, S. aureus, Salmonella typhimurium, E. coli, Listeria monocytogenes, Streptococcus pyogenes* (Mir et al., 2022) and *Bacillus subtillis.* Research by Washino et al. (1986) indicated for the first time that *Arctium lappa* extracts also have antifungal activity, inhibiting the growth of *Candida albicans, Aspergillus niger,*and *Penicillium hirsutum* (de Souza et al., 2022).

The results also showed that macerates from *Linum usitatissimum* were the least effective in limiting the growth of the fungi tested against *Thielaviopsis basicola* (ø5.67 mm), macerates from *Levisticum officinale* against *Fusarium culmorum* (ø5.97 mm), decoctions of *Verbascum thapsiforme* against the growth of *Fusarium culmorum* (ø5.87 mm), macerates of *Artemisia absinthium* against growth inhibition of *Thielaviopsis basicola* (ø6.33 mm) and decoctions of *Arctium lappa* against *Fusarium culmorum* (ø6.03 mm). The results obtained are reflected in a study by Amin and Thakur (2014), who showed that aqueous and alcoholic extracts of *Linum usitatissimum* L. exhibit an antimicrobial activity against *Salmonella typhimurium* and *E. coli* (Amin and Thakur, 2014). According to Narender et al. (2016), the antimicrobial effect of flax extracts may be a direct result of their chemical composition. Indeed, extracts are abundant in a range of phenolic compounds, lignans, and fatty acids. The particularly strong sensitivity of bacterial strains to *Linum usitatissimum* extracts is linked to the stimulation of bacterial DNA degradation by phenolic compounds. In addition, the lignans contained in the extracts have been attributed to a role in the destruction of microbial cell walls (Hussien and Aziz, 2021).

Summarizing the research results obtained, the great potential of plant extracts in agriculture should be highlighted. So far, research into their use as biostimulants are ongoing, which is linked to the development of sustainable and ecological forms of crop management. Biostimulant extracts can simultaneously improve the growth, development, and yield of crops while being effective in disease control. It is important to emphasize the fact that such agricultural inputs are produced from natural sources, thus reducing chemical and toxic effects on the environment. According to Santoyo et al. (2012) and Junaid et al. (2013), the biostimulatory and bioprotective effects of plant extracts may be due to growth promotion, antagonism, lysis, and induction of defense enzymes as responsible for fighting plant diseases. Studies by Akula and Ravishankar (2011) and Abdel-Monaim et al. (2012) indicate the mechanisms responsible for the bioprotective effects of extracts related to the inhibition of pathogenic microbial strains. In general, according to Amadioha (2000), plant extracts can

be effectively used in the control of crop diseases, but following the principle of their preventive rather than curative application (Gebashe et al., 2021).

Conclusions

The study demonstrated the potential of aqueous extracts in the form of infusions, decoctions, and macerates, extracted from burdock roots, wormwood leaves, lovage roots, flax seeds, and mullein flowers as bioprotectants, capable of inhibiting the growth of fungi that cause soybean diseases. The growth of the tested fungal strains was most strongly inhibited by extracts from *Linum usitatissimum* and *Levisticum officinale*. Fungi, isolated from the soybean, showed the least sensitivity to extracts, produced from *Arctium lappa*. The observation of fungal growth reduction in *in vitro* tests proved that extracts in the form of decoctions and infusions had the strongest effect. The results of the study indicate that extracts can be included as an option for phytopathogens control in soybean cultivation. This is because they have the ability and potential not only to increase productivity but also to reduce the development of fungal diseases.

The antifungal activity of aqueous botanical extracts suggests a possible role played by secondary metabolites, extracted by hot and cold extraction processes. However, further research in this area is indicated, especially under real field conditions, where this effect may be influenced by environmental factors. Data available in the literature on the ecological control of soybean pathogens is still limited, so plant extracts can be considered as candidates for the development of bioprotectants. However, it should be emphasized that these preliminary in vitro results provide a novel opportunity to discover new products for use in crop protection.

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OD BIOSTYMULATORÓW DO MOŻLIWYCH BIOLOGICZNYCH ŚRODKÓW OCHRONY ROŚLIN

Streszczenie. Wodne ekstrakty roślin z udowodnionym działaniem biostymulującym mogą posiadać zdolność hamowania wzrostu i rozwoju grzybów wywołujących choroby roślin. Potencjalne zastosowanie ekstraktów w takiej roli ma wiele zalet w tym fakt, że ekstrakty są biodegradowalne, mniej kosztowne i dostępne od ręki. Zatem, celem badania było przeprowadzenie oceny potencjału infuzji wodnych, wywarów i maceratów, ekstrahowanych z korzenia łopianu, liści piołunu, korzenia lubczyku, ziaren lnu, dziewanny drobnokwiatowej jako biologicznych środków ochrony roślin. To badanie zostało przeprowadzone przez badanie w warunkach in vitro zdolności tych bioprotektantów do hamowania wzrostu grzybów *Thielaviopsis basicola* (Berk. and Broome), oraz *Fusarium avenaceum* (Fr.) Sacc, *Fusarium culmorum* (Wm.G. Sm.) Sacc., *Fusarium sambucinum* (Fuckel), *Fusarium solani* (Mart.) Sacc., *Rhizoctonia solani* (J.G. Kühn), *Botrytis cinerea* Pers., *Sclerotinia sclerotiorum* (Lib. de Bary),które powodują chorobę soi. Działanie grzybobójcze maceratów, infuzji oraz wywarów określone za pomocą metody dyfuzji na szalkach Petriego na podłożu stałym PDA wykazało potencjał badanych ekstraktów wodnych jako bioprotektantów zdolnych do powstrzymania wzrostu grzybów powodujących choroby soi.

Słowa kluczowe: patogeny, ekstrakty wodne, działanie grzybobójcze, macerat, infuzja, wywar