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Antibacterial and nematocidal activities of extracts of plants of the families Poaceae, Cyperaceae, Asparagaceae, Convolvulaceae, Crassulaceae, Rosaceae, Lamiaceae, and Boraginaceae

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Plant-based drugs are broadly used against microorganisms that cause diseases in people and animals. Nonetheless, their potential has not yet been studied to the fullest. In *in vitro* conditions, we tested ethanol extracts from the leaves, stems, and roots of 20 species of plants against ten species of bacteria, one fungus, and free-living stages of larvae of ruminant nematodes (L_1 *Muellerius capillaris*, L_{1-3} *Strongyloides papillosus*, L_3 *Haemonchus contortus*). Eight-millimeter growth inhibition zones of the colonies were produced by the following ethanol extracts: shoot-and-leaf and root extracts of *Prunus fruticosa* against eight species of microorganisms (*Escherichia coli*, *Klebsiella pneumoniae*, *Proteus mirabilis*, *Shigella flexneri*, *Pseudomonas aeruginosa*, *Enterococcus faecalis*, *Staphylococcus aureus*, and *Bacillus subtilis*); shoot-and-leaf and root extracts of *Salvia nutans* – against eight species (*E. coli*, *P. mirabilis*, *E. faecalis*, *Listeria monocytogenes*, *S. aureus*, *B. subtilis*, *Clostridium perfringens*, and *Candida albicans*); shoot-and-root extract of *Hylotelephium telephium* – against seven species (*E. coli*, *K. pneumoniae*, *P. mirabilis*, *Sh. flexneri*, *P. aeruginosa*, *E. faecalis*, and *B. subtilis*); shoot-and-leaf and root extracts of *Koeleria gracilis* – against six species (*K. pneumoniae*, *P. mirabilis*, *E. faecalis*, *L. monocytogenes*, *S. aureus*, and *B. subtilis*); shoot-and-leaf and root extracts of *Asparagus officinalis* – against six species (*P. mirabilis*, *Sh. flexneri*, *P. aeruginosa*, *L. monocytogenes*, *C. perfringens*, and *C. albicans*); shoot-and-leaf extract of *Cuscuta* sp. – against six species (*K. pneumoniae*, *P. mirabilis*, *Sh. flexneri*, *L. monocytogenes*, *C. perfringens*, and *C. albicans*); leaf, fruit, and root extracts of *Prunus spinosa* – against six species (*E. coli*, *P. mirabilis*, *P. aeruginosa*, *E. faecalis*, *S. aureus*, and *B. subtilis*); shoot-and-leaf and root extracts of *Salvia nemorosa* – against six species (*E. coli*, *P. aeruginosa*, *E. faecalis*, *L. monocytogenes*, *S. aureus*, and *C. perfringens*); shoot-and-leaf extract of *Carex hirta* – against five species (*K. pneumoniae*, *P. mirabilis*, *P. aeruginosa*, *L. monocytogenes*, and *B. subtilis*); shoot-and-leaf and root extracts of *Stachys sylvatica* – against four species (*Sh. flexneri*, *L. monocytogenes*, *C. perfringens*, and *C. albicans*); and leaf, stem, seed, and root extracts of *Lithospermum officinale* were effective against four species of microorganisms (*E. coli*, *L. monocytogenes*, *S. aureus*, and *B. subtilis*). However, the nematocidal action of the alcohol extracts of the studied plants was produced by only two plants: *Stachys recta* and *Lithospermum officinale*. Thus, as a result of 24 h exposure to the 0.1% solutions of extracts from these plants, mortality was observed in 46.9% and 59.2% of the cases, respectively. Nonetheless, based on the results of the study, these plants were recognized as promising for further research on *in vivo* nematocidal activity. During the search of antibacterial and antifungal activities, less promising were the extracts from the following plants: the shoots and leaves, and roots of *Setaria viridis*, *Phlomoides tuberosa*, *Marrubium vulgare*, and the roots of *Poa trivialis*, *Calamagrostis epigejos*, and *Convolvulus arvensis*.

Keywords: leaves; stem; root; seed; growth inhibition zone; bacterial colonies; polyresistant strain; parasitic nematode.

Introduction

Plants and the biological systems that surround them play essential roles in supporting the health and well-being of the plant and its inhabitants in the future (Henkhaus et al., 2020). On Earth, there are about 350,000 species of higher plants, although only a small share of these species have been studied in detail. At the same time, there are numerous scientific reports confirming that many medicinal plants have immunomodulating, immunostimulating, antidiabetic, anticarcinogenic, antimicrobial, and antioxidant properties. These properties align with traditional folk medicine practices, and scientific studies have corroborated their effectiveness (Rodino & Butu, 2019; van Wietmarschen, 2020). Medicinal and aromatic plants are a valuable natural basis for enriching the existing functional products or developing new ones, oriented at the needs of particular groups of consumers. Their value stems from a broad spectrum of structurally diverse bioactive compounds with proven health benefits health (Borovuk & Zazharska, 2022; Kolchyk et al., 2024). Therefore, the scientific community has been actively studying the potentials of selected plants, taking into account the stable demand for new medicinal and aromatic plants, new approaches to production of extracts and essential oils, and also study on synergic action of bioactive compounds of different origins. A subject of special interest is their use for the development of effective functional beverages with notable anti-inflammatory, antioxidant, antimicrobial, and other beneficial properties (Maleš et al., 2022).

Recently, the use of medicinal and aromatic plants has been gaining popularity due to a specific content of nutrients (amino acids and fatty acids) and bioactive molecules (volatile and non-volatile), because of their biological effects and health benefits. Bioactive molecules are stored in the leaves, flowers, fruits, seeds, bark, and roots, and they mostly include phenolic compounds (phenolic acids, flavonoids, tannins, anthocyanins, lignans, and stilbens), essential oil, terpenoids, alkaloids, phytosterols, and saponins. The aromatic peculiarities of medicinal and aromatic plants are mainly associated with volatiles of essential oils, but the presence of non-volatile compounds such as phenolic compounds also contributes to their specific sensory properties. Phytochemical profiling of plant species that contain specific and complex mixtures of bioactive molecules reveals new problems related to their isolation using regular and advanced methods of extraction, as well as detecting potential biological effects. Higher plants

synthesize hundreds or even thousands of various chemical compounds characterized by a broad range of biological activity. Among them, especially valuable are antimicrobial compounds that are able to effectively inhibit the growth and development of microorganisms that are causative agents of diseases in both plants and people (Amenu, 2014; Zazharskyi et al., 2023; Melnychuk et al., 2024). Antioxidant and antimicrobial effects have been confirmed for extracts from *Equisetum arvense*, *Humulus lupulus*, *Tagetes patula*, *Sambucus* spp., and *Taraxacum officinale* (Rodino & Butu, 2019).

During experiments, the researchers discovered an antibacterial potential of ethanol extract of *Hypericum lydium* against *Staphylococcus aureus* (Aygül & Şerbetçi, 2020). Drugs based on plants of the Asteraceae family are extensively used to combat human and animal pathogens (Gotsulya et al., 2020; Zazharskyi et al., 2024b). There was confirmed an in vitro antibacterial effect of leaf extract of *Murraya koenigii*, which promoted the destruction of the cellular membrane of pathogenic bacteria (Abuga et al., 2020). Ethyl-acetate and aqueous extracts from the leaf of *Goniothalamus wynaadensis* Bedd. (Annonaceae) demonstrated a strong activity toward the bacteria *Salmonella typhi*, *Escherichia coli*, and *Staphylococcus aureus*, and also inhibited the metabolic vitality of cancer cells (Sharma et al., 2019). Organic extracts obtained from the root of *Nicotiana tabacum* exerted antioxidant, anti-cancer, and antimicrobial properties, despite the fact that tobacco smoking remains the main risk factor of lung cancer development (Al-Lahham et al., 2020). Due to their immunological properties, various plant extracts can activate or inhibit immunological processes in the skin. Plant-based preparations remain an important alternative to modern pharmaceutical drugs and can be effectively used to mitigate various skin diseases, in particular, infected wounds, herpes, and other viruses, bacterial and fungal diseases, and allergic reactions (Sitarek et al., 2020).

Phytosynthesis of metal nanoparticles is a simple and reliable method for their production and application. In particular, nanoparticles of copper oxide (CuO-NP) were successfully synthesized using leaf extract of the plant *Colocasia esculenta*, which served as a stabilizer and bioreductor (as a capping and bio-reducing agent) in the process of formation of nanoparticles (Pal et al., 2024). There was developed an ecological method for producing nickel particles by using natural raw material, in particular, the method of green synthesis using extract from the plant *Fumaria officinalis* (Khalugarova et al., 2023).

The role of plants in combating antibiotic resistance is impossible to overestimate (Chacón et al., 2019; Yamada et al., 2020; Saki et al., 2020). Strains of *Staphylococcus aureus*, *Escherichia coli*, *Enterococcus faecalis*, and *Klebsiella pneumonia*, which have been identified as resistant to antibiotics, were used to study the antibacterial and antioxidant properties of essential oils from *Rosmarinus officinalis* L., *Zingiber officinale* Roscoe, *Melaleuca alternifolia* Cheel, *Cymbopogon winterianus*, *Salvia sclarea* L., and *Syzygium aromaticum* (Imane et al., 2020). Combination of *Aloe vera* (L.) Burm. F. and ceftiofur or cloxacillin slowed the development of chromosomal resistance in strains of *S. aureus*. Due to the synergic and additive effects, such a combination allows reducing the doses of antibiotics when treating clinical manifestations of mastitis in dairy cattle (Chacón et al., 2019; Sklyarov et al., 2020). Extract from *Pithecellobium clypearia* can potentially be used as a therapeutic agent against *Acinetobacter baumannii* and *Pseudomonas aeruginosa*, and also increase the effectiveness of antibiotics (Liu et al., 2019).

The objective of our study was to assess the antibacterial and nematocidal effects of 20 alcohol extracts against 11 species of microorganisms and free-living larvae of three species of nematodes of ruminants. So far, those plants have been studied insufficiently in terms of antimicrobial and nematocidal effects, and can have a large potential in modern human and veterinary medicine.

Material and methods

The stems, leaves, roots, and fruits of 20 species of plants were collected in Dnipropetrovsk Oblast (Ukraine), dried at a room temperature, fragmented, weighed, and stored for 10 days in 70% ethyl alcohol, and then filtrated. Per 100 g of 70% ethyl alcohol, we took 10 g of dry fragmented plants. Then, to evaluate the antibacterial properties, 0.1 mL of filtrated alcohol extracts was placed on 6 mm-diameter paper disks. The disks were dried in sterile conditions at a 10 ºC temperature in a HR1200-IIA2-D microbiological safety cabinet (China).

The antibacterial activity of the plant tinctures was assessed using the disk diffusion method in agar. From the 24 h inoculations of ethanol strains of microorganisms, we prepared weighed amounts, according to the standard bacterial suspension turbidity, equaling 0.5 units of density according to McFarland (McF) 1.5 x 10^8 CFU (colony-forming units), which were determined using a DEN-1 densitometer (Latvia, Table 1).

Table 1
Taxonomic composition of 11 species of microorganisms we studied

Phylum, division	Family	Species, strains
Proteobacteria	Enterobacteriaceae	*Escherichia coli* 055 ATCC 8739
		Klebsiella pneumoniae ATCC 13883
		Proteus mirabilis ATCC 14153
		Shigella flexneri GISK 232054
	Pseudomonadaceae	*Pseudomonas aeruginosa* ATCC 15442
Firmicutes	Enterococcaceae	*Enterococcus faecalis* ATCC 29212
	Listeriaceae	*Listeria monocytogenes* ATCC 19112
	Staphylococcaceae	*Staphylococcus aureus* ATCC 25923
	Bacillaceae	*Bacillus subtilis* ATCC 6633
	Clostridiaceae	*Clostridium perfringens* ATCC 13124
Ascomycota	Saccharomycetaceae	*Candida albicans* ATCC 2091

The obtained weighed amount was transferred to Mueller-Hinton agar (Himedia, India, 2023) with subsequent cultivation in a TCO-80/1 thermostat (Factory of Novel Technologies and Marketing of Medical Equipment of Ukraine, 2015) for 24 h at a 37 ºC temperature. Over the inoculations, we placed disks (n = 8) saturated with alcohol tinctures of 20 species of plants (Table 2).

Table 2
Parts of the 20 species of plants that we used to prepare ethanol extracts and the most important data on their antibacterial activities

Family	Species	Used part of plant	Most important literature sources about medical properties of the plant
Poaceae	Green foxtail *Setaria viridis* (L.)	shoots and leaves	Yu (2020)
		root	Yu (2020)
	Yellow foxtail *Setaria pumila* (Poir.)	shoots and leaves	Oleti & Shrestha (2024)
		root	Dowsett & McGill (2018)
	Prairie Junegrass *Koeleria macrantha* (Ledeb.)	shoots and leaves	Koc Koyun & Hakki (2022)
		root	Somaratne & Xu (2025)
	Rough bluegrass *Poa trivialis* L.	root	Falkowski & Maruszewska (2015)
	Wood small-reed *Calamagrostis epigejos* (L.) Roth	root	Mehdiyeva & Müller (2024)
Cyperaceae	Hairy sedge *Carex hirta* L.	shoots and leaves	Murugappan & Jones (2022)
Asparagaceae	Asparagus *Asparagus officinalis* L.	shoots and leaves	Santos & Freitas (2020)
		root	Drost (2023)
Convolvulaceae	Dodder (parasitic plant) *Cuscuta* sp.	shoots and leaves	Sharma & Gupta (2021)
	Field bindweed *Convolvulus arvensis* L.	root	Özkil & Üremiş (2023); Bussmann & Noureddine (2024)

Family	Species	Used part of plant	Most important literature sources about medical properties of the plant
Crassulaceae	Orpine *Hylotelephium telephium* (L.) H. Ohba	shoots and leaves	Đukić, & Jovanović. (2021)
		root	Arvia & Zakrzewska (2024); Li & Zhai (2024)
Rosaceae	Common agrimony *Agrimonia eupatoria* L.	shoots and leaves	Bussmann & Kikvidze (2020)
		root	Marković & Stankov Jovanović (2021)
	European dwarf cherry *Prunus fruticosa* Pall.	shoots and leaves	Tsafouros & Roussos (2024)
		root	Hrotkó & Halász (2019); Davaagerel & Nyambayar (2024)
	Blackthorn *Prunus spinosa* L.	leaves	Marčetić & Vidović (2022)
		fruits	Temiz & Okumuş (2023)
		root	Ucak Ozkaya (2025)
Lamiaceae	Hedge woundwort *Stachys sylvatica* L.	shoots and leaves	Apostolescu & Neamtu (2023)
		root	Mukhamedsadykova & Malm (2024)
	Phlomis pungens Willd.	shoots and leaves	Bazavluk & Novikov (2020)
		root	Gostin (2023)
	Sage-leaf mullein *Phlomoides tuberosa* (L.) Moench	shoots and leaves	Kholbutayeva & Kizi (2024)
		root	Barghout & El Had (2020)
	Woodland sage *Salvia nemorosa* L.	shoots and leaves	Mahdieh & Akhani (2018); Yang & Yue (2024)
		root	Fotovvat & Rejali (2024)
	Nodding sage *Salvia nutans* L.	shoots and leaves	Gál & Kačániová (2023)
		root	Tekeli & Bezgin (2025)
	White horehound *Marrubium vulgare* L.	shoots and leaves	Ouasti & Bussmann (2024)
		root	Kanyonga & Kavunga (2024)
Boraginaceae	Common gromwell *Lithospermum officinale* L.	shoots and leaves	Mehdiyeva & Kikvidze (2024)
		seed	Mehdiyeva & Kikvidze (2024)
		root	Mollaei & Ebadi (2019); Ahmad & Molin (2022)

As a positive control, we used disks with 10 µg of ampicillin trihydrate (Himedia Laboratories Pvt. Limited, Mumbai, Maharashtra, India), a broad-range semisynthetic antibiotic (Valle et al., 2015). After 24 h, the growth of the cultures was measured using an antibiotic zone scale (Antibiotic Zone Scale-C, model PW297, India) and the software TpsDig2 (F. James Rohlf, USA, 2016). The data in the tables are presented as x ± SD (mean ± standard deviation).

The nematocidal properties of the plants were studied using 0.1% solutions of 10% ethanol extracts (100 g of 70% ethanol/10 g of plant): 0.1 mL of 10% extract/10 mL of H_2O.

The feces were collected manually from ruminants naturally infected with the nematodes *Muellerius capillaris* (Mueller, 1889), *Strongyloides papillosus* (Wedl, 1856), and *Haemonchus contortus* ((Rudolphi, 1803) Cobb, 1898). The larvae of digestive-system nematodes (*S. papillosus* and *H. contortus*) were cultivated for 10 days at a 18–22 °C temperature. The detection of the larvae was conducted according to the generally accepted Baermann's technique (Zajac, 2011) using a centrifuge (1,500 rpm for 4 min). The larvae were identified according to the morphological features (Van Wyk et al., 2004, 2013; Gugosyan et al., 2019).

A volume of 0.1 mL of sediment containing larvae from the centrifuged test tubes were placed into Eppendorf tubes of 1.5 capacity. Then, we added 1 mL of each solution of ethanol extract with 24 h exposure in five repetitions at 22 °C. After this period, we counted live and dead larvae (immobile, with signs of damage to the intestinal integrity).

Results

The tested alcohol extracts inhibited some strains of microorganisms of the families Enterobacteriaceae, Pseudomonadaceae, Enterococcaceae, Listeriaceae, Staphylococcaceae, Bacillaceae, Clostridiaceae, and Saccharomycetaceae (Tables 3–5). The highest inhibitory action toward *E. coli* was exerted by the alcohol extracts from the shoot and leaf of *L. officinale*, *H. telephium*, roots of *S. nemorosa*, *S. nutans*, and *P. fruticosa* (17.3, 13.6, 12.6, 12.5, and 12.2 mm, hereinafter the average radius of growth inhibition zone is given in mm). A moderate ability to inhibit the growth of *E. coli* was demonstrated by the roots of *S. pumila* (8.2), *C. arvensis* (11.4), *P. spinosa* (8.4), and *M. vulgare* (10.5). At the same time, we observed a resistance of the isolate of *E. coli* to the alcohol extracts of *S. viridis*, *P. trivialis*, *C. epigejos*, *C. hirta*, *A. officinalis*, *Cuscuta* sp., *A. eupatoria*, *S. sylvatica*, *Ph. pungens*, and *Ph. tuberosa*. Ampicillin, which we used as a positive control, demonstrated no efficacy against *E. coli*, indicating the bacterium's resistance to this drug (Table 3).

A strong antibacterial effect against *K. pneumoniae*, exceeding that of ampicillin, was produced by the plant extracts from the shoots and leaves of *K. gracilis* (10.6), *C. hirta* (10.3), *Cuscuta* sp. (17.6), *H. telephium* (11.6), *Ph. pungens* (11.3), and root of *P. fruticosa* (10.4). The extracts from the shoots and leaves of *A. eupatoria* (8.3), *P. fruticosa* (5.4), *L. officinale* (5.6), and root of *S. pumila* (8.6) exhibited a moderate ability to inhibit the growth of colonies of *K. pneumoniae*, suggesting a partial antibacterial effect of these plant components. It should be noted that the strain of *K. pneumoniae* was completely insensitive to the ethyl extracts from *S. viridis*, *P. trivialis*, *C. epigejos*, *C. arvensis*, *A. eupatoria*, *S. sylvatica*, *Ph. tuberosa*, *S. nemorosa*, *S. nutans*, and *M. vulgare*: the growth of these bacterial colonies underwent no changes, which which casts doubts on the antimicrobial activity of these extracts. At the same time, ampicillin in the control exerted no antimicrobial activity against *K. pneumoniae*.

As confirmed by the disk diffusion method, *P. mirabilis* was observed to be highly susceptible to seven alcohol extracts of the shoots and leaves of *K. gracilis* (10.5), *C. hirta* (8.2), *A. officinalis* (10.2), *Cuscuta* (22.5), *P. fruticosa* (10.7), *S. nutans* (12.3), and *M. vulgare* (10.7), and four extracts from the roots of *S. viridis* (11.7), *P. trivialis* (10.5), *C. epigejos* (11.7), and *Ph. pungens* (13.7). The bacterium was found to be moderately sensitive to the shoot-and-leaf and root extracts of *H. telephium* (5.7 and 8.4), fruit and root extracts of *P. spinosa* (10.7 and 8.4), and seed extract of *L. officinale* (5.3). The shoot-and-leaf and root extracts of *C. arvensis*, *A. eupatoria*, *S. sylvatica*, *Ph. tuberosa*, *S. nemorosa*, and *L. officinale* exhibited no antimicrobial activity against the polyresistant strain of *P. mirabilis*.

The alhol extracts of the plants demonstrated a notable antibacterial activity against *Sh. flexneri*. We observed a high level of inhibition produced by the shoot-and-leaf extracts of *A. officinalis* (13.6), *Cuscuta* sp. (15.3), *H. telephium* (16.3), *P. fruticosa* (10.5), *Ph. tuberosa* (12.5), the root extract of *C. epigejos* (13.3), and also the shoot-and-leaf and root extracts of *S. sylvatica* (13.6 and 8.6). The strain of *Sh. flexneri* was resistant to certain plant extracts: the shoots and leaves, and roots of *S. viridis*, *S. pumila*, *K. gracilis*, *A. eupatoria*, *Ph. pungens*, *S. nutans*, and *M. vulgare*, roots of *P. trivialis* and *C. arvensis*, leaf of *C. hirta*, and leaf, fruit, and root of *P. spinosa*.

The strains of *P. aeruginosa* and *E. faecalis*, which belong to the families Pseudomonadaceae and Enterococcaceae, were resistant to ampicillin (Table 4). The growth of *P. aeruginosa* was effectively inhibited by the alcohol extracts of the shoots and leaves, and roots of *H. telephium* (each 8.5), *P. fruticosa* (10.8 and 12.2), fruits of *P. spinosa* (10.4), leaves of *C. hirta* (8.3), *M. vulgare* (11.3), and roots of *A. officinalis* (8.7) and *S. nemorosa* (10.3).

A notable antimicrobial activity against *E. faecalis* was demonstrated by six extracts: the shoot and leaf, and root of *S. nutans* (10.5 and 15.5), leaf of *H. telephium* (14.4), and roots of *K. gracilis* (8.6), *P. fruticosa* (13.7), *P. spinosa* (12.3), and *S. nemorosa* (10.2).

Table 3
Antibacterial effect of ethanol extracts of plants on *Escherichia coli*, *Klebsiella pneumoniae*, *Proteus mirabilis*, and *Shigella flexneri* (x ± SD, n = 8)

Species	*E. coli*		*K. pneumoniae*		*P. mirabilis*		*Sh. flexneri*	
	test	control	test	control	test	control	test	control
Setaria viridis (L.)								
– shoots and leaves	0 ± 0	1.32 ± 0.23	0 ± 0	1.12 ± 0.25	0 ± 0	19.42 ± 3.51	0 ± 0	16.03 ± 2.31
– root	0 ± 0	1.27 ± 0.36	0 ± 0	0 ± 0	11.74 ± 1.42	20.16 ± 4.34	0 ± 0	17.54 ± 2.18
Setaria pumila (Poir.)								
– shoots and leaves	0 ± 0	1.42 ± 0.34	2.28 ± 0.37	1.26 ± 0.31	0 ± 0	20.35 ± 2.62	0 ± 0	18.35 ± 3.12
– root	8.23 ± 1.16	2.06 ± 0.22	8.62 ± 1.34	1.59 ± 0.44	8.49 ± 1.23	20.41 ± 2.27	0 ± 0	18.23 ± 2.44
Koeleria macrantha (Ledeb.)								
– shoots and leaves	2.44 ± 0.37	1.22 ± 0.18	10.57 ± 1.53*	0 ± 0	10.51 ± 1.35*	20.53 ± 3.11	0 ± 0	16.64 ± 2.11
– root	3.52 ± 0.18	1.41 ± 0.24	0 ± 0	1.31 ± 0.18	0 ± 0	19.24 ± 2.35	0 ± 0	18.12 ± 3.67
Poa trivialis L.								
– root	0 ± 0	1.28 ± 0.21	0 ± 0	1.13 ± 0.25	10.54 ± 1.41*	20.28 ± 2.14	0 ± 0	17.36 ± 3.24
Calamagrostis epigejos (L.) Roth.								
– root	0 ± 0	1.37 ± 0.32	0 ± 0	1.64 ± 0.12	11.73 ± 1.46*	20.12 ± 2.52	13.28 ± 1.72*	18.11 ± 3.35
Carex hirta L.								
– shoots and leaves	0 ± 0	2.16 ± 0.22	10.34 ± 1.27*	1.32 ± 0.23	8.15 ± 1.32	19.20 ± 2.41	0 ± 0	17.24 ± 2.38
Asparagus officinalis L.								
– shoots and leaves	0 ± 0	1.60 ± 0.13	2.46 ± 0.23	0 ± 0	10.22 ± 1.41	20.03 ± 2.56	13.64 ± 1.52*	17.52 ± 3.44
– root	0 ± 0	1.43 ± 0.27	0 ± 0	1.42 ± 0.26	0 ± 0	20.62 ± 3.35	0 ± 0	18.23 ± 3.51
Cuscuta sp.	0 ± 0	1.54 ± 0.14	17.39 ± 1.61	1.64 ± 0.22	22.47 ± 1.82	19.26 ± 3.14	15.31 ± 1.85	16.24 ± 3.66
Convolvulus arvensis L.								
– root	11.44 ± 1.73	1.27 ± 0.19	0 ± 0	1.87 ± 0.31	0 ± 0	20.43 ± 2.29	0 ± 0	18.25 ± 3.19
Hylotelephium telephium (L.) H. Ohba								
– shoots and leaves	13.57 ± 1.21*	2.13 ± 0.33	11.63 ± 1.46*	1.35 ± 0.43	5.72 ± 0.87	20.22 ± 3.43	16.34 ± 1.80	16.23 ± 2.14
– root	0 ± 0	1.34 ± 0.27	0 ± 0	1.12 ± 0.26	8.41 ± 1.66	19.81 ± 2.54	0 ± 0	16.41 ± 2.36
Agrimonia eupatoria L.								
– shoots and leaves	0 ± 0	1.48 ± 0.32	8.34 ± 0.76	1.84 ± 0.32	2.15 ± 0.32	19.37 ± 2.92	0 ± 0	17.32 ± 2.84
– root	0 ± 0	1.37 ± 0.21	0 ± 0	1.22 ± 0.23	0 ± 0	19.53 ± 2.37	0 ± 0	16.03 ± 2.51
Prunus fruticosa Pall.								
– shoots and leaves	0 ± 0	2.44 ± 0.13	5.43 ± 0.62	1.24 ± 0.33	10.66 ± 1.32	19.66 ± 2.52	10.54 ± 1.91	16.51 ± 2.35
– root	12.16 ± 1.43	1.82 ± 0.35	10.42±1.94**	1.86 ± 0.41	0 ± 0	19.17 ± 3.23	2.48 ± 0.22	16.24 ± 3.63
Prunus spinosa L.								
– leaves	2.47 ± 0.34	1.58 ± 0.24	2.42 ± 0.34	1.39 ± 0.54	0 ± 0	20.34 ± 3.65	0 ± 0	17.13 ± 2.08
– fruits	0 ± 0	1.22 ± 0.13	0 ± 0	1.83 ± 0.36	10.65 ± 1.73*	19.12 ± 2.53	0 ± 0	16.41 ± 2.33
– root	8.42 ± 1.20	2.01 ± 0.26	0 ± 0	1.14 ± 0.31	8.41 ± 1.74	20.71 ± 3.14	0 ± 0	16.25 ± 3.22
Stachys sylvatica L.								
– shoots and leaves	0 ± 0	1.64 ± 0.27	0 ± 0	1.91 ± 0.43	0 ± 0	19.23 ± 2.52	13.56 ± 1.35*	16.12 ± 2.24
– root	0 ± 0	1.88 ± 0.43	0 ± 0	0 ± 0	0 ± 0	20.16 ± 3.44	8.63 ± 1.77	16.21 ± 3.05
Phlomis pungens Willd.								
– shoots and leaves	0 ± 0	2.42 ± 0.34	11.28 ± 1.43*	1.37 ± 0.42	0 ± 0	20.41 ± 2.63	0 ± 0	17.62 ± 3.27
– root	0 ± 0	1.26 ± 0.31	0 ± 0	1.94 ± 0.41	13.68 ± 1.34	19.37 ± 2.49	0 ± 0	16.21 ± 2.40
Phlomoides tuberosa (L.) Moench.								
– shoots and leaves	0 ± 0	2.09 ± 0.26	0 ± 0	0 ± 0	0 ± 0	19.43 ± 3.24	12.49 ± 1.84*	16.02 ± 1.63
– root	0 ± 0	1.37 ± 0.21	0 ± 0	1.43 ± 0.16	0 ± 0	19.52 ± 3.16	0 ± 0	16.46 ± 2.18
Salvia nemorosa L.								
– shoots and leaves	0 ± 0	2.32 ± 0.35	0 ± 0	1.82 ± 0.33	0 ± 0	20.31 ± 2.82	5.12 ± 0.64	16.93 ± 2.52
– root	12.56 ± 1.22*	1.23 ± 0.74	0 ± 0	0 ± 0	0 ± 0	20.67 ± 3.34	0 ± 0	16.11 ± 2.24
Salvia nutans L.								
– shoots and leaves	0 ± 0	2.41 ± 0.52	0 ± 0	1.54 ± 0.43	12.32 ± 1.47*	20.18 ± 3.45	0 ± 0	17.36 ± 3.45
– root	12.51 ± 1.24	1.64 ± 0.33	0 ± 0	1.29 ± 0.22	0 ± 0	19.52 ± 3.13	0 ± 0	16.43 ± 2.64
Marrubium vulgare L.								
– shoots and leaves	0 ± 0	2.56 ± 0.41	0 ± 0	2.32 ± 0.45	10.73 ± 1.26*	20.62 ± 3.41	0 ± 0	17.32 ± 2.43
– root	10.45 ± 1.13*	1.39 ± 0.54	0 ± 0	1.61 ± 0.23	0 ± 0	20.24 ± 3.23	0 ± 0	16.15 ± 3.27
Lithospermum officinale L.								
– shoots and leaves	17.33 ± 1.94*	1.82 ± 0.38	5.62 ± 0.88	2.46 ± 0.24	0 ± 0	19.22 ± 3.94	0 ± 0	16.11 ± 2.93
– seed	0 ± 0	1.47 ± 0.43	0 ± 0	1.72 ± 0.15	5.27 ± 1.51	19.51 ± 2.43	0 ± 0	17.47 ± 3.62
– root	0 ± 0	1.52 ± 0.62	0 ± 0	1.33 ± 0.62	0 ± 0	20.47 ± 3.32	5.40 ± 0.21	16.02 ± 2.64

Note: * – disks with 10.0 μg of ampicillin were used for all bacteria as positive control.

Table 4
Antibacterial effect of ethanol extracts of plants on *Pseudomonas aeruginosa*, *Enterococcus faecalis*, and *Listeria monocytogenes* (x ± SD, n = 8)

Species	*P. aeruginosa*		*E. faecalis*		*L. monocytogenes*	
	test	control	test	control	test	control
Green foxtail *Setaria viridis* (L.)						
– shoots and leaves	0 ± 0	1.62 ± 0.34	0 ± 0	1.42 ± 0.25	0 ± 0	32.14 ± 3.71
– root	0 ± 0	1.57 ± 0.23	0 ± 0	1.31 ± 0.18	0 ± 0	30.28 ± 3.52
Yellow foxtail *Setaria pumila* (Poir.)						
– shoots and leaves	2.26 ± 0.37	1.48 ± 0.25	0 ± 0	1.24 ± 0.39	0 ± 0	35.42 ± 3.53
– root	0 ± 0	1.61 ± 0.32	0 ± 0	1.28 ± 0.22	0 ± 0	33.24 ± 3.66

Species	*P. aeruginosa*		*E. faecalis*		*L. monocytogenes*	
	test	control	test	control	test	control
Prairie Junegrass *Koeleria macrantha* (Ledeb.)						
– shoots and leaves	2.27 ± 0.35	1.64 ± 0.43	0 ± 0	0 ± 0	10.32 ± 1.61	37.05 ± 3.34
– root	0 ± 0	1.46 ± 0.28	8.64 ± 1.31	0 ± 0	0 ± 0	34.72 ± 3.18
Rough bluegrass *Poa trivialis* L.						
– root	2.23 ± 0.22	1.81 ± 0.25	0 ± 0	1.48 ± 0.21	0 ± 0	33.62 ± 4.21
Wood small-reed *Calamagrostis epigejos* (L.) Roth						
– root	0 ± 0	1.37 ± 0.23	0 ± 0	1.34 ± 0.32	0 ± 0	31.43 ± 3.15
Hairy sedge *Carex hirta* L.						
– shoots and leaves	8.34 ± 1.13	1.72 ± 0.34	0 ± 0	1.57 ± 0.43	14.38 ± 1.62	34.17 ± 3.32
Asparagus *Asparagus officinalis* L.						
– shoots and leaves	0 ± 0	1.59 ± 0.31	0 ± 0	1.31 ± 0.16	10.41 ± 1.16	32.82 ± 3.14
– root	8.72 ± 1.54	1.43 ± 0.22	0 ± 0	1.53 ± 0.24	0 ± 0	34.13 ± 3.52
Dodder (parasitic plant) *Cuscuta* sp.	0 ± 0	1.72 ± 0.26	0 ± 0	0 ± 0	22.37 ± 1.82	35.22 ± 3.46
Field bindweed *Convolvulus arvensis* L.						
– root	0 ± 0	1.33 ± 0.31	0 ± 0	1.44 ± 0.17	0 ± 0	33.51 ± 3.04
Orpine *Hylotelephium telephium* (L.) H. Ohba						
– shoots and leaves	8.46 ± 1.71	1.58 ± 0.32	14.35 ± 1.42*	1.52 ± 0.23	2.41 ± 1.60	34.46 ± 3.82
– root	8.53 ± 1.42	1.61 ± 0.47	0 ± 0	1.48 ± 0.42	0 ± 0	33.53 ± 3.25
Common agrimony *Agrimonia eupatoria* L.						
– shoots and leaves	0 ± 0	1.72 ± 0.24	0 ± 0	1.35 ± 0.24	0 ± 0	32.34 ± 3.73
– root	0 ± 0	1.82 ± 0.33	0 ± 0	1.51 ± 0.36	0 ± 0	30.83 ± 3.64
European dwarf cherry *Prunus fruticosa* Pall.						
– shoots and leaves	10.78 ± 1.32*	1.82 ± 0.23	0 ± 0	1.64 ± 0.31	0 ± 0	31.34 ± 3.16
– root	12.24 ± 1.71***	1.67 ± 0.31	13.72 ± 1.53*	1.39 ± 0.53	0 ± 0	34.52 ± 3.21
Blackthorn *Prunus spinosa* L.						
– leaves	0 ± 0	1.73 ± 0.28	0 ± 0	1.46 ± 0.32	0 ± 0	33.63 ± 2.94
– fruits	10.36 ± 1.43*	1.55 ± 0.32	0 ± 0	1.62 ± 0.27	0 ± 0	31.02 ± 3.25
– root	0 ± 0	1.84 ± 0.46	12.34 ± 1.70*	1.35 ± 0.44	0 ± 0	32.24 ± 3.32
Hedge woundwort *Stachys sylvatica* L.						
–shoots and leaves	0 ± 0	1.67 ± 0.32	0 ± 0	1.63 ± 0.34	10.49 ± 1.63*	30.36 ± 3.43
– root	0 ± 0	1.83 ± 0.41	0 ± 0	1.42 ± 0.35	0 ± 0	32.41 ± 3.12
Phlomis pungens Willd.						
– shoots and leaves	0 ± 0	1.75 ± 0.34	0 ± 0	1.52 ± 0.31	0 ± 0	32.22 ± 3.47
– root	0 ± 0	1.81 ± 0.43	0 ± 0	1.43 ± 0.47	0 ± 0	31.52 ± 3.24
Sage-leaf mullein *Phlomoides tuberosa* (L.) Moench						
– shoots and leaves	0 ± 0	1.64 ± 0.28	0 ± 0	1.24 ± 0.32	15.54 ± 1.82	33.13 ± 3.06
– root	0 ± 0	1.72 ± 0.44	0 ± 0	1.37 ± 0.22	0 ± 0	32.44 ± 3.12
Woodland sage *Salvia nemorosa* L.						
– shoots and leaves	2.58 ± 0.46	1.77 ± 0.35	0 ± 0	1.73 ± 0.41	15.83 ± 1.81*	31.25 ± 3.11
– root	10.34 ± 1.72*	1.83 ± 0.42	10.23 ± 1.70*	1.68 ± 0.52	10.26 ± 1.83*	30.62 ± 3.24
Nodding sage *Salvia nutans* L.						
– shoots and leaves	0 ± 0	1.67 ± 0.41	10.52 ± 1.25	1.55 ± 0.22	0 ± 0	30.93 ± 3.25
– root	0 ± 0	1.74 ± 0.33	15.47 ± 1.23*	0 ± 0	8.24 ± 1.72	31.24 ± 3.52
White horehound *Marrubium vulgare* L.						
– shoots and leaves	11.25 ± 1.13*	1.83 ± 0.46	0 ± 0	1.39 ± 0.43	0 ± 0	32.13 ± 3.44
– root	0 ± 0	1.62 ± 0.25	0 ± 0	1.24 ± 0.21	0 ± 0	32.46 ± 3.31
Common gromwell *Lithospermum officinale* L.						
– shoots and leaves	0 ± 0	1.76 ± 0.32	0 ± 0	1.63 ± 0.42	10.42 ± 1.61*	30.29 ± 3.54
– seed	0 ± 0	1.84 ± 0.43	0 ± 0	1.44 ± 0.35	0 ± 0	31.12 ± 3.06
– root	0 ± 0	1.75 ± 0.42	0 ± 0	1.32 ± 0.24	0 ± 0	32.23 ± 3.17

Note: see Table 3.

Table 5

Antibacterial effects of ethanol extracts of plants on *Staphylococcus aureus*, *Bacillus subtilis*, *Clostridium perfringens*, and *Candida albicans* (x ± SD, n = 8)

Species	*S. aureus*		*B. subtilis*		*C. perfringens*		*C. albicans*	
	test	control	test	control	test	control	test	control
Setaria viridis (L.)								
– shoots and leaves	0 ± 0	36.23 ± 4.54	2.58 ± 1.31	1.34 ± 0.22	0 ± 0	14.36 ± 1.52	0 ± 0	14.63 ± 1.89
– root	0 ± 0	37.32 ± 4.25	0 ± 0	1.27 ± 0.43	0 ± 0	15.23 ± 1.84	0 ± 0	15.12 ± 2.64
Setaria pumila (Poir.)								
– shoots and leaves	0 ± 0	35.17 ± 4.62	0 ± 0	1.24 ± 0.32	0 ± 0	14.42 ± 1.63	0 ± 0	14.27 ± 2.32
– root	0 ± 0	36.25 ± 4.13	0 ± 0	1.33 ± 0.25	0 ± 0	15.52 ± 1.46	0 ± 0	15.11 ± 1.93
Koeleria macrantha (Ledeb.)								
– shoots and leaves	17.31 ± 1.64	37.43 ± 4.08	8.47 ± 1.62	1.36 ± 0.23	2.33 ± 1.08	14.14 ± 2.23	0 ± 0	14.25 ± 1.66
– root	0 ± 0	36.21 ± 4.36	0 ± 0	1.32 ± 0.21	0 ± 0	15.27 ± 1.72	0 ± 0	14.38 ± 2.52
Poa trivialis L.								
– root	0 ± 0	37.06 ± 4.22	2.29 ± 0.37	1.43 ± 0.42	0 ± 0	15.43 ± 1.55	0 ± 0	14.54 ± 1.82
Calamagrostis epigejos (L.) Roth								
– root	0 ± 0	35.54 ± 3.81	0 ± 0	1.35 ± 0.34	0 ± 0	14.32 ± 1.74	0 ± 0	15.16 ± 2.63
Carex hirta L.								
– shoots and leaves	5.63 ± 0.92	36.32 ± 4.14	11.65 ± 1.53*	1.27 ± 0.23	0 ± 0	15.24 ± 1.82	0 ± 0	14.22 ± 2.45

Species	*S. aureus*		*B. subtilis*		*C. perfringens*		*C. albicans*	
	test	control	test	control	test	control	test	control
Asparagus officinalis L.								
– shoots and leaves	0 ± 0	36.17 ± 4.23	0 ± 0	1.34 ± 0.32	12.74 ± 1.31	15.32 ± 1.36	12.76 ± 1.32	14.61 ± 2.37
– root	0 ± 0	35.52 ± 4.05	0 ± 0	1.37 ± 0.29	0 ± 0	14.43 ± 1.71	0 ± 0	14.24 ± 2.52
Cuscuta sp.	0 ± 0	34.23 ± 4.16	0 ± 0	1.44 ± 0.22	10.57 ± 1.46	14.26 ± 1.52	10.53 ± 1.61	15.28 ± 2.53
Convolvulus arvensis L.								
– root	0 ± 0	36.24 ± 4.32	0 ± 0	1.24 ± 0.32	0 ± 0	14.33 ± 1.54	0 ± 0	14.63 ± 1.92
Hylotelephium telephium (L.) H. Ohba								
– shoots and leaves	0 ± 0	35.16 ± 3.43	10.36 ± 1.72*	1.21 ± 0.37	0 ± 0	14.62 ± 1.44	0 ± 0	14.43 ± 1.68
– root	0 ± 0	37.42 ± 4.21	0 ± 0	1.34 ± 0.23	0 ± 0	15.18 ± 1.63	0 ± 0	15.01 ± 2.32
Agrimonia eupatoria L.								
– shoots and leaves	0 ± 0	35.35 ± 3.82	0 ± 0	1.32 ± 0.22	0 ± 0	14.71 ± 1.46	0 ± 0	14.94 ± 2.51
– root	8.18 ± 1.73	36.32 ± 4.41	0 ± 0	1.34 ± 0.32	11.34 ± 1.72*	14.13 ± 1.62	0 ± 0	14.82 ± 2.23
Prunus fruticosa Pall.								
– shoots and leaves	0 ± 0	36.03 ± 4.26	12.64 ± 1.33*	1.45 ± 0.32	0 ± 0	15.44 ± 1.62	0 ± 0	15.22 ± 2.75
– root	10.25 ± 1.81*	36.27 ± 3.42	0 ± 0	1.33 ± 0.40	0 ± 0	14.22 ± 1.53	0 ± 0	14.63 ± 1.94
Prunus spinosa L.								
– leaves	0 ± 0	37.42 ± 4.35	0 ± 0	1.46 ± 0.31	0 ± 0	15.18 ± 1.72	0 ± 0	15.09 ± 1.62
– fruits	0 ± 0	36.63 ± 3.24	10.21 ± 1.42*	1.32 ± 0.25	0 ± 0	15.31 ± 1.43	0 ± 0	15.24 ± 2.50
– root	8.54 ± 1.40	37.11 ± 4.48	0 ± 0	1.44 ± 0.23	0 ± 0	14.52 ± 1.60	0 ± 0	14.37 ± 1.31
Stachys sylvatica L.								
– shoots and leaves	0 ± 0	37.24 ± 4.03	0 ± 0	1.42 ± 0.27	10.76 ± 1.73	14.22 ± 1.43	10.17 ± 1.34	14.13 ± 1.74
– root	0 ± 0	36.44 ± 3.25	0 ± 0	1.34 ± 0.31	0 ± 0	14.35 ± 1.52	0 ± 0	15.42 ± 2.36
Phlomis pungens Willd.								
– shoots and leaves	0 ± 0	34.26 ± 3.53	0 ± 0	1.32 ± 0.26	0 ± 0	15.12 ± 2.56	0 ± 0	15.20 ± 2.32
– root	6.45 ± 0.21	35.32 ± 4.24	10.62 ± 1.33*	1.33 ± 0.22	0 ± 0	15.43 ± 1.87	0 ± 0	15.51 ± 2.14
Phlomoides tuberosa (L.) Moench								
– shoots and leaves	0 ± 0	37.42 ± 4.51	0 ± 0	1.37 ± 0.28	0 ± 0	15.54 ± 2.31	0 ± 0	14.43 ± 2.27
– root	0 ± 0	36.33 ± 4.46	0 ± 0	1.44 ± 0.23	0 ± 0	14.46 ± 1.52	0 ± 0	15.03 ± 2.42
Salvia nemorosa L.								
– shoots and leaves	0 ± 0	36.37 ± 4.22	0 ± 0	1.42 ± 0.35	0 ± 0	14.42 ± 2.26	0 ± 0	14.92 ± 2.64
– root	11.34 ± 1.82*	36.54 ± 4.35	0 ± 0	1.31 ± 0.22	20.41 ± 1.26*	15.14 ± 1.33	0 ± 0	15.28 ± 2.22
Salvia nutans L.								
– shoots and leaves	2.37 ± 0.42	36.12 ± 3.24	0 ± 0	1.43 ± 0.24	10.52 ± 1.13	14.25 ± 1.62	10.16 ± 1.32	15.10 ± 1.92
– root	12.51 ± 1.70*	34.53 ± 4.28	10.14 ± 1.62	1.26 ± 0.32	0 ± 0	15.33 ± 1.48	0 ± 0	15.66 ± 2.23
Marrubium vulgare L.								
– shoots and leaves	0 ± 0	36.63 ± 4.34	0 ± 0	1.52 ± 0.34	0 ± 0	14.41 ± 2.65	0 ± 0	14.13 ± 1.48
– root	2.48 ± 0.21	35.22 ± 4.24	0 ± 0	1.42 ± 0.21	0 ± 0	14.12 ± 1.86	0 ± 0	15.52 ± 2.44
Lithospermum officinale L.								
– shoots and leaves	0 ± 0	34.84 ± 4.53	11.73 ± 1.44*	1.53 ± 0.42	0 ± 0	14.73 ± 1.42	0 ± 0	14.02 ± 1.65
– seed	14.51 ± 1.66	36.02 ± 4.31	12.65 ± 1.32*	1.36 ± 0.34	0 ± 0	15.54 ± 1.63	0 ± 0	15.32 ± 2.16
– root	0 ± 0	35.34 ± 4.42	0 ± 0	1.32 ± 0.23	0 ± 0	15.27 ± 1.74	0 ± 0	14.25 ± 1.61

Note: see Table 3.

Among the studied samples, a substantial inhibition of *L. monocytogenes* was achieved by the alcohol extracts from the leaf and root of *S. nemorosa* (15.8 and 10.3), shoots and leaves of *K. macrantha* (10.3), *C. hirta* (14.4), *A. officinalis* (10.4), *Cuscuta* sp. (22.4), *S. sylvatica* (10.5), *Ph. tuberosa* (15.5), *L. officinale* (10.4), and root of *S. nutans* (8.2).

According to the results (Table 5), the ethanol extracts of the shoot and leaves of *K. macrantha* (17.3), root of *A. eupatoria* (8.2), *P. fruticosa* (10.3), *P. spinosa* (8.5), *S. nemorosa* (11.3), *S. nutans* (12.5), and seed of *L. officinale* (14.5) exhibited significant antimicrobial activities against *S. aureus*. The bacterium had a moderate sensitivity to the alcohol shoot-and-leaf extracts of *C. hirta* (5.6) and *Ph. pungens* (6.5). The studies revealed that the alcohol extracts from the shoots and leaves of *K. macrantha* (8.5), *C. hirta* (11.7), *H. telephium* (10.4), *P. fruticosa* (12.6), fruit of *P. spinosa* (10.2), root of *Ph. pungens* (10.6), *S. nutans* (10.1), and leaf and seed of *L. officinale* (11.7 and 12.7) effectively inhibited the growth of the colonies of *B. subtilis*. As a result of the study, we determined that the strain of *B. subtilis* was resistant to ampicillin. A significant ability to inhibit the growth of *C. perfringens* was displayed by six extracts: the shoots and leaves of *A. officinalis* (12.7), *Cuscuta* sp. (10.6), *S. sylvatica* (10.8), *S. nutans* (10.5), and roots of *A. eupatoria* (11.3) and *S. nemorosa* (20.4). We should note that the strain was insensitive to the ethyl extracts of *S. viridis*, *S. pumila*, *P. trivialis*, *C. epigejos*, *C. arvensis*, *H. telephium*, *P. fruticosa*, *P. spinosa*, *Ph. pungens*, *P. tuberosa*, *M. vulgare*, and *L. officinale*.

The greatest antifungal action toward *C. albicans* (inhibition zone >10 mm, Table 5) was demonstrated by four alcohol extracts – only shoot-and-leaf extracts – of *A. officinalis* (12.8), *Cuscuta* sp. (10.5), *S. sylvatica* (10.2), and *S. nutans* (10.2). Furthermore, the polyresistant strain was not inhibited by the extracts from *S. viridis*, *S. pumila*, *K. macrantha*, *P. trivialis*, *C. epigejos*, *C. hirta*, *C. arvensis*, *H. telephium*, *A. eupatoria*, *P. fruticosa*, *P. spinosa*, *Ph. pungens*, *Ph. tuberosa*, *S. nemorosa*, *M. vulgare*, and *L. officinale*.

The studies on the nematocidal action of alcohol extracts of the medicinal plants revealed the effects on the vitality of the nematode larvae produced by the plants *Lithospermum officinale* and *Stachys recta*. The mortality of the larvae after 24 h exposure to these extracts was on average 59.2% and 46.9%, respectively. However, such an effect was observed only against the larvae of *S. papillosus*. At the same time, we determined an insignificant effect of 0.1% solution of alcohol extract from *Asparagus officinalis*, only against the larvae of *S. papillosus* as well (about 28.8% on average). The larvae of other species of nematodes (*H. contortus*, *M. capillaris*) were found to be much more resistant to extracts of these species: we registered no dead larvae after subjection to the extracts (Table 6).

Discussion

Recenty, there has been a growing interst to the use of medicinal and aromatic plants, and also their components in food and pharmaceutical industries, and also various other spheres. (Boyko & Brygadyrenko, 2020, 2022). This is due to their unique compositions of nutrients (in particular, amino acids and fatty acids) and bioactive molecules, both volatile and non-volatile, which have a number of positive biological effects and have proven benefits for health. Those compounds accumulate in different part of plants – leaves, flowers, fruits, seeds, bark, and roots – and are represented by mostly phenolic compounds (in particular, phenolic acids, flavonoids, tannins, anthocyanins, lignans, and stilbens, essential oils, terpenoids, alkaloids,

phytosterols, and saponins). The aromatic properties of such plants are mostly due to the volatile components of essential oils, although non-volatile compounds, especially phenols, also significantly contribute to their biological activities. Secondary metabolites of plants are able to inhibit the growth of bacterial pathogens affecting humans and animals. Some of the studied species have a potential for further pharmaceutical use (Abuga et al., 2020; Zazharskyi et al., 2024c, 2025). A detailed phytochemical profiling of species that contain complex mixtures of bioactive compounds defines new objectives for effective isolation of these compounds using traditional and modern methods of extraction, and also for study of their potential biological activities (Maleš et al., 2022). Plant essential oils and extracts from *Lavandula angustifolia* (Lamiaceae), *Cymbopogon citratus* (Poaceae), *Mentha piperita* (Lamiaceae), and also extracts from *Chenopodium ambrosioides* (Amaranthaceae), *Aloe ankoberensis*, and *Aloe pulcherima* (Asphodelaceae) exerted bactericidal actions toward *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*. Moreover, these extracts were confirmed to have a better antimicrobial effect than extracts of petroleum ether and chloroform (Gishen et al., 2020).

Table 6

Nematocidal activities (%) of the extracts from medicinal plants against the larvae of the nematodes L_1 *Muellerius capillaris*, $L_{1–3}$ *Strongyloides papillosus*, L_3 *Haemonchus contortus* (x ± SD, n = 5)

Plant	Part of the plant	*S. papillosus* control	*S. papillosus* 10%	*H. contortus* control	*H. contortus* 10%	*M. capillaris* control	*M. capillaris* 10%
Agrimonia eupatoria L.	root	9.2 ± 8.5	7.9 ± 11.4	0.0 ± 0.0	0.0 ± 0.0	0.7 ± 1.5	0.0 ± 0.0
	shoot and leaf	9.6 ± 9.3	5.8 ± 8.1	0.0 ± 0.0	0.0 ± 0.0	5.4 ± 7.4	5.1 ± 7.0
Prunus spinosa L.	root	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	fruit	8.2 ± 7.8	13.4 ± 12.4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	leaf	0.0 ± 0.0	4.1 ± 4.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Prunus fruticosa Pall.	shoot and leaf	0.6 ± 1.4	6.1 ± 4.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Marrubium vulgare L.	root	3.9 ± 5.4	3.5 ± 4.9	0.0 ± 0.0	0.0 ± 0.0	3.6 ± 3.5	3.6 ± 4.9
	shoot and leaf	0.0 ± 0.0	2.0 ± 4.5	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Salvia nemorosa L.	root	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	shoot and leaf	0.0 ± 0.0	2.5 ± 3.6	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Salvia nutans L.	root	9.2 ± 8.5	13.3 ± 13.1	0.0 ± 0.0	0.0 ± 0.0	0.7 ± 1.5	1.7 ± 2.4
	shoot and leaf	0.0 ± 0.0	2.7 ± 2.5	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Stachys recta L.	root	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	shoot and leaf	0.6 ± 1.4	46.9 ± 22.9	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Phlomis pungens Willd.	root	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	shoot and leaf	5.6 ± 6.3	4.9 ± 4.8	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Phlomis tuberosa L.	root	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	shoot and leaf	3.4 ± 4.8	3.6 ± 5.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Convolvulus arvensis L.	root	9.2 ± 8.5	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.7 ± 1.5	0.6 ± 1.4
Hylotelephium telephium (L.) H.Ohba	root	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	shoot and leaf	7.6 ± 7.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Cuscuta sp.	whole plant	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Galium verum L.	root	7.6 ± 7.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Asparagus officinalis L.	root	7.6 ± 7.3	2.5 ± 5.6	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	shoot and leaf	0.0 ± 0.0	28.8 ± 3.9	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Carex nigra (L.)	shoot and leaf	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Calamagrostis epigejos (L.) Roth.	root	0.0 ± 0.0	4.5 ± 4.4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Festuca valesiaca Schleich.	root	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	3.1 ± 2.9
Koeleria gracilis Pers.	root	9.2 ± 8.5	9.4 ± 9.0	0.0 ± 0.0	0.0 ± 0.0	0.7 ± 1.5	3.4 ± 3.6
	shoot and leaf	0.0 ± 0.0	3.6 ± 5.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Setaria pumila L.	root	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	shoot and leaf	0.0 ± 0.0	2.8 ± 3.9	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Setaria viridis L.	shoot and leaf	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Lithospermum officinale L.	root	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	shoot and leaf	0.0 ± 0.0	1.6 ± 3.6	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
	seed	1.5 ± 3.4	59.2 ± 18.4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0

In this study, we tested various parts of plants to verify reports about bactericidal effects of extracts from their leaves, roots, and fruits. The leveas of *Ipomoea pes-caprea* (Convolvulaceae) are a good source of various phytocomponents, especially phenolic compounds and flavonoids. Acetonic extract of the leaves of *Ipomoea pes-caprea* exerted powerful antioxidant and antibacterial effects (Alagesan et al., 2019). Sayout et al. (2020) observed the essential oil from *Lavandula tenuisecta* (Lamiaceae) to be active against all the tested species of Gram-negative and Gram-positive bacteria, except *Salmonella* spp. Studies also confirmed the inhibitory, antioxidant, antimicrobial, and cytotoxic potentials of enzymes involved in the metabolism of carbohydrates and lipids in Anchusa ovata (Boraginaceae) (Jaradat et al., 2020).

In the previous experiments, we studied alcohol tinctures of 12 species of plants of the Asteraceae family for their activity toward 10 species of pathogenic microorganisms, one fungus, and larvae of three nematodes parasitizing ruminants. A promising avenue for future research has been identified in the bactericidal activity of Asteraceae plants (Zazharskyi et al., 2024b). One of the significant plants of this family is *Xanthium strumarium* L. In the previous in vitro studies, we tested ethanol, ethyl-ether, and dimethyl-sulfoxide extracts from the fruit, leaf, shoot, and root of *X. strumarium* L. (Asteraceae) for their activity against 13 species of bacteria and larvae of three species of nematodes, confirming bactericidal effect of all parts of the plants (Zazharskyi et al., 2024a).

The yielded results indicate that alcohol extracts are characterized by a broad spectrum of antimicrobial activity, effectively inhibiting the growth of microorganisms of the families Enterobacteriaceae, Enterococcaceae, Listeriaceae, Staphylococcaceae, Bacillaceae, Clostridiaceae, and fungi of the family Saccharomycetaceae. The results are consistent with the data obtained by Amenu et al. (2024): polyphenol-rich spices and extracts of herbs revealed a potential for inhibition of the growth of fungi and protection from aflatoxins. Amenu et al. (2024) explored the potentials of various plants to inhibit fungi that affect sweet orange in Ethiopia, discovering effectiveness of extracts from *Vernonia amygdalina*, *Ginger oficealae*, and *Pterolobium stalatam* against *Penicilium* spp., *Aspergillus* spp., *Rhizopus* spp., *Mucor* spp., and *Fusarium* spp.

At the same time, according to our own results, individual tested strains – in particular, *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, *Enterococcus faecalis*, and *Bacillus subtilis* – demonstrated a high resistance to ampicillin, as confirmed by the absence of inhibition zones or their minimal sizes (0.0–2.0 mm).

In our previous studies of the nematocidal properties of medicinal plants, we saw an action of a 3% aqueous extract of *Asparagus officinalis* L. on the larvae of the nematode *S. papillosus* (Boyko & Brygadyrenko, 2021). The results of our experiment also confirm the nematocidal properties of this plant after using a 0.1% solution of alcohol extract, which further can be used for development of measures against animal nematodiases.

In our previous experiments (Boyko & Brygadyrenko, 2021), we registered an insignificant effect on the larvae of *S. papillosus* produced by the 3% aqueous extracts from the shoots of *Calamagrostis epigejos* (L.) and *Convolvulus arvensis* L. Roth. (on average, the mortality measured 53.2% and 57.4%, compared with 22.5% and 11.8% in the control, respectively). Less effective were the 0.1% solutions of alcohol extracts from the roots of these plants, with mortality of *S. papillosus* observed in 4.5% of the larvae and only after subject to *C. epigejos*. The shoots and leaves of *Agrimonia eupatoria* L., *Phlomis pungens* Willd., and *Salvia nutans* L. also caused no nematocidal effects in 0.1% solutions of alcohol extracts, unlike the 3% aqueous solutions of *A. eupatoria* (leaves), *Ph. pungens*, and *S. nutans* (shoots) (Boyko & Brygadyrenko, 2021).

Unlike other plants, *Stachys recta* L. showed one of the best results in terms of nematocidal properties both in alcohol and aqueous solutions of extracts. Death of the larvae of *S. papillosus* was produced by 0.1% solution of alcohol shoot-and-leaf extract of this plant in 46.9% of the cases. This agrees with the results of our previous studies (Boyko & Brygadyrenko, 2021) where we observed death of over 95% of the larvae of *S. papillosus* subject to the 3% aqueous solution of leaf extract of this plant (on average 96.7%, compared with 27.8% in the control).

Conclusion

For the first time, there was a study of the complex inhibitory actions of 20 species of plants of eight families (Poaceae, Cyperaceae, Asparagaceae, Convolvulaceae, Crassulaceae, Rosaceae, Lamiaceae, and Boraginaceae) in relation to 10 strains of bacteria, one strain of fungi, and larvae of three nematodes of ruminants. The alcohol extracts from the shoot and leaf, and root of *S. viridis*, roots of *P. trivialis*, *C. epigejos*, *C. arvensis*, and shoots and leaves, and roots of *Ph. tuberosa* and *M. vulgare* exerted no notable antimicrobial activity against the multiresistant strains of *E. coli*, *K. pneumoniae*, *P. mirabilis*, *Sh. flexneri*, *P. aeruginosa*, *E. faecalis*, *L. monocytogenes*, *S. aureus*, *B. subtilis*, *C. perfringens*, and *C. albicans*. The ethanol extracts displayed a significant antimicrobial action toward the multiresistant strains of bacteria and fungus, in particular, shoot-and-leaf extracts of *S. pumila* and *A. eupatoria*, shoot-and-leaf and root extracts of *Ph. pungens* were effective against three strains; shoot-and-leaf and root extracts of *S. sylvatica*, leaf, stem, seed, and root extracts of *L. officinale* were active against four strains; and shoot-and-leaf extract of *C. hirta* effectively inhibited the growth of five of the 11 studied strains of microorganisms. The ethanol extracts of *P. fruticosa*, *S. nutans*, *H. telephium*, *K. gracilis*, *A. officinalis*, *Cuscuta* sp., *P. spinosa*, and *S. nemorosa*, and also their individual components are promising for further studies oriented at combating polyresistant microorganisms. At the same time, we observed nematocidal properties of two alcohol extracts of plants against the larvae of the nematode *S. papillosus*. Twenty-four-hour exposure to the 0.1% solutions of alcohol extracts of *Stachys recta* and *Lithospermum officinale* produced 46.9% and 59.2% mortality of the larvae, respectively. These results can be useful in the future for treatment and prophylaxis measures against strongyloidiasis of ruminants.

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