

IRSTI: 37.24.01

<https://doi.org/10.70264/jbr.v1.3.2026.1>

MYCOBIOTA AND ANTIFUNGAL ACTIVITY OF SOME PLANT COMPONENTS OF THE FLORA OF AZERBAIJAN

Konul F. Bakhshaliyeva^{1,2}, Muradov P.Z.^{1,2*}, Rafiga Z. Nagiyeva¹, Dilara T. Khalilova², Sabina A. Shirinova³, Aynur Kh. İsgenderova², Fidan R. Mammadova³, Nargiz S. Maharramli, Maryam B. Aliyeva¹, Suraya İ. Jafarli²

¹ Institute of Molecular Biology, Public Legal Entity of the Ministry of Science and Education of the Republic of Azerbaijan, Baku, Republic of Azerbaijan.

² Sumgait State University, Sumgait, Republic of Azerbaijan.

³Baku State University, Baku, Republic of Azerbaijan.

*Corresponding author: Muradov P.Z., mpanah@mail.ru

ABSTRACT

Some plants (*Agropyrum repens* L., *Alhagi pseudoalhagi* (M.Bieb.) Desv. ex Wangerin, *Allium rubellum* M. Bieb., *Calendula officinalis* L., *Daucus carota* L., *Mentha spicata* L., *Poa bulbosa* L., *Rosa canina* L., *Trifolium pratense* L. and *Viola tricolor* L.) belonging to the flora of the Republic of Azerbaijan, distributed on the Absheron Peninsula were studied for the species composition of their mycobiota and the antimicrobial activity of their constituent components. It became clear that a total of 67 fungal species are involved in the formation of the mycobiota of the studied plants. These fungi include toxigens, allergens, phytopathogens, opportunistic pathogens, and endophytes. In addition to being one of the habitats of fungi, they also contain components with antimicrobial activity. Among these components, essential oils are characterized by more active indicators.

Keywords: Azerbaijani flora, mycobiota, constituent components, antimicrobial activity.

Received: August 07, 2026 / Accepted: September 03, 2026 / Published: September 07, 2026

© The Author(s) 2026.

Citation: Bakhshaliyeva K.F., Muradov P.Z., Nagiyeva R.Z., Khalilova D.T., Shirinova S.A., İsgenderova A.Kh., Mammadova F.R., Maharramli N.S., Aliyeva M.B., Jafarli S.İ. Mycobiota and antifungal activity of some plant components of the flora of Azerbaijan. Journal of Biological Research, 1(3), 1-7. <https://doi.org/10.70264/jbr.v1.3.2026.1>.

1. INTRODUCTION

One of the characteristic features of the modern period is the ever-increasing human intervention in nature, as a result of which various problems are beginning to appear on Earth. The deterioration of the environmental situation, the depletion of biodiversity, desertification, salinization and other similar phenomena are no longer felt within the boundaries of a single country, but on a regional and global scale. One of the manifestations of this is the emergence of new diseases and a more severe course of existing diseases [1]. As a result, a weakening of the immunological resistance of people is clearly observed [2]. Therefore, the above circumstances necessitate, or rather, an urgent need, to find means that can prevent these problems and strengthen the human immune system, and obtaining them from natural sources is considered the most appropriate. One of such natural sources are plants, which contain a wide range of biologically, including pharmacologically, active substances with various effects [3]. Despite this, the number of plants currently used for this purpose or serving as raw materials for the production of drugs with

pharmacological activity is extremely small compared to the number of plant species known to science. It is enough to note that the total number of plant species known to science is about 400,000 [4], the number of essential oil plants is 2500–3000 [5], while the number of plants from which pharmacologically active substances are obtained under industrial conditions is extremely small [6].

The Republic of Azerbaijan has a rich nature, and in its relatively small territory there is a wide range of plants that are important in terms of the above mentioned tasks and generally belong to the category of useful plants. Currently, the number of plant species included in the flora of Azerbaijan is approaching 5000 [7]. However, today, medicinal products of high medical value and intended for use in clinical practice, especially on an industrial scale, are practically not produced from plants that are widely grown in the country. It should be noted that a number of plants of the flora of Azerbaijan have been comprehensively studied in botanical, pharmacological, mycological and other aspects, and 1075 plant species included in the

flora of the country were recognized as promising from a pharmacognostic point of view and recommended for further study as natural sources of biologically, including pharmacologically, active substances [8]. In our opinion, this figure does not reflect modern realities, since the main source for its determination was the publication "Flora of Azerbaijan", published in Russian in 1952. The data from that period are largely outdated and reflect only part of the properties characteristic of certain plants. More precisely, in our opinion, the statement based on information from that time cannot currently be considered fully consistent with reality.

Taking into account all of the above, the aim of the presented work is to evaluate the antifungal activity of the components of a number of plants included in the flora of Azerbaijan.

2. MATERIALS AND METHODS

2.1 Plant selection

To study the mycobiota and constituent components of plants belonging to the Azerbaijani flora, species such as *Agropyrum repens* L., *Alhagi pseudoalhagi* (M.Bieb.) Desv. ex Wangerin, *Allium rubellum* M. Bieb., *Calendula officinalis* L., *Daucus carota* L., *Mentha spicata* L., *Poa bulbosa* L., *Rosa canina* L., *Trifolium pratense* L., and *Viola tricolor* L., which are medicinal and have sufficient resources not only on the Absheron Peninsula (40° 25' 0" N, 49° 20' 0" E) but throughout the Republic. In both cases, samples were taken from the aboveground parts of the plants. To study the antimicrobial activity of the components, the collected samples were air-dried and ground into powder in a laboratory mill.

2.2 Isolation, identification and cultivation of pure cultures of fungi

For the separation of test cultures, samples were also taken from soils exposed to anthropogenic impact. Samples for the study were taken from the areas of the Absheron Peninsula of the Republic of Azerbaijan. The collected soil samples were collected in sterile bags and delivered to the laboratory within a short time (within 2-4 hours), a 10% extract was prepared, which was diluted (10-100 times) and inoculated into a nutrient medium, and a pure culture was obtained using known methods [9-11]. The isolated pure cultures were identified by classical mycological methods based on known identifiers [12-14]. In this case, macroscopic (color, shape, edges, color of the back of the colony, etc.) and microscopic (shape of the sac, the number of spores in it, the shape and size of conidia carriers and conidia, phialides, etc.) structural elements of the obtained pure cultures were determined, and the species composition was determined by identification based on the corresponding determinant. For microscopic examination of microstructural elements, a digital laboratory trinocular microscope OMAX 40X-2500X LED with a USB camera was used. Samples taken from plants, more precisely samples from the area suspected of containing the fungus, were obtained as pure cultures either directly or by washing the area with sterile water and transferring the wash water to the culture medium, and identified according to the procedure described above. In total, more than 350 plant samples and 56 soil samples were taken during the research and analyzed in accordance with the purpose of the study.

For the taking fungi to the pure cultures were used nutrient media such as agarized malt juice (AMJ), rice (RA), starch (SA) and potato (PA) agars, agarized Capek and Capek-Doks media. Preparation, sterilization, and pouring of media into Petri dishes were carried out according to known methods accepted in microbiology [15].

For the cultivation of fungi in a liquid nutrient medium, Čapek medium was used, the composition of which was as follows (g/l): Glucose – 14,0; CaCO₃ – 0,7; KNO₃ – 0,7; MgSO₄ – 0,35; NaCl – 0,35; K₂HPO₄ – 0,35; FeSO₄ – traces; distilled water – 1 L.

2.3 Antifungal activities

To determine the antifungal activities of the studied plants were used aqueous (10%), alcoholic extracts (3%) obtained from their air-dried aerial parts collected during the flowering phase, and essential oils obtained by hydrodistillation methods [16]. The process was evaluated based on the amount of biomass (BM) produced (g/l). As a control, were taken biomass produced by the fungi on Čapek medium without addition plant-means agent. To implement these, methods and approaches used in the work of various authors [17-18] were used.

As a test cultures were used fungi, which were isolated from the soil during the study, according to the classical methods [19] described above.

2.4 Statistical analysis

During the research, all experiments were repeated 4-6 times and the results were statistically analyzed [20]. In all cases, results that met the formula $\sigma/M = P \leq 0.05$ (where M is the mean value of the replicates, σ is the standard deviation, and P is the Student's test) were considered valid and used in this article.

3. RESULTS

During the research, the plants selected as the object of study first was studied for their species composition of mycobiota, and it was determined that in total, 67 fungal species participate in the formation of their mycobiota. These fungi differ both from each other and in the form of their participation in the mycobiota of individual plants. Their numerical characteristics are given in Table 1. The fungi identified in the studies included 7 species (*Actinomucor elegans*, *Mortierella alpina*, *Mucor circinelloides*, *M.hiemalis*, *M.mucedo*, *M.rasemous* and *Rhizopus stolonifera*) belonging to the *Mucormycota* and 60 species to the *Ascomycota* divisions, while 53 species of ascomycota fungi (*Alternaria alternata*, *A.radicina*, *A.solani*, *Aspergillus flavus*, *A. nidulans*, *A. niger*, *A.ochraceus*, *A.repens*, *A.ustus*, *A.versicolor*, *Aureobasidium pullulans*, *Botrytis cinerea*, *Cephalosporium lecani*, *Cercospora beticola*, *C.fabae*, *C.medicaginis*, *Cladosporium cladosporides*, *C. herbarum*, *C.gossypii*, *C. tramschellii*, *Fusarium culmorum*, *F.oxysporum*, *F.solani*, *F. verticillioides* (= *F. moniliforme*), *Gliocladium roseum*, *Macrosporium commune*, *M.macrosporium*, *Penicillium brevicompactum*, *P.chrysogenum*, *P.cyclopium*, *P.expanseum*, *P.funiculosum*, *P.glacum*, *P.janthinellum*, *Prubrum*, *Phoma fallens*, *Ph.betae*, *Ph.destructiva*, *Ph.medicaginis*, *Ramularia betae*, *R.medicaginis*, *Sphaceloma menthae*,

Table 1 – Numerical characteristics of fungal species involved in the formation of the mycobiota of the studied plants.

Plant species	Mucormucota	Ascomucota	Bazidiomucota	Total
<i>Agropyrum repens</i> L.,	1	10	1	12
<i>Alhagi pseudoalhagi</i> (M.Bieb.) Desv. ex Wangerin, L.	2	15	2	19
<i>Allium rubellum</i> M. Bieb.	0	11	1	12
<i>Calendula officinalis</i> L.,	1	12	1	14
<i>Daucus carota</i> L.,	1	7	1	9
<i>Mentha spicata</i> L.,	1	6	0	7
<i>Poa bulbosa</i> L.,	0	8	0	8
<i>Rosa canina</i> L.,	1	12	1	14
<i>Trifolium pratense</i> L.	2	17	2	21
<i>Viola tricolor</i> L.	1	9	0	10
Total	2	59	6	67

Talaromyces purpurogenus, *Thielaviopsis basicola*, *Trichoderma asperellum*, *T.hamatum*, *T.harzianum*, *T.koningi*, *T. viride*, *Trichotectum roseum*, *Verticillium album*, *V.dahile* and *V. nigrescens*) species to anamorphs, and 7 species (*G. fujikuroi*, *M. sitophila*, *P. herbarum*, *Sclerotinia laxa*, *S.sclerotiorum*, *S.trifoliorum*, *S. helianthi*, *S.nodorum*, *S.sojina*, *S. botryosum*) to teleomorphs. has been determined to belong. As for the distribution of fungi on plants and soil, it was clear from the results that only 17 species of fungi (*Botrytis cinerea*, *Cercospora beticola*, *C. fabae*, *C. medicaginis*, *Ph. betae*, *Ramularia betae*, *R. medicaginis*, *Sphaceloma menthae*, *Sclerotinia laxa*, *S. sclerotiorum*, *S. trifoliorum*, *Septoria helianthi*, *S. nodorum*, *Thielaviopsis basicola* Tr. *roseum*, *Verticillium album* and *V.dahile*) in plants, 20 (*Actinomucor elegans*, *A. flavus*, *A. nidulans*, *A. niger*, *A. ochraceus*, *A. repens*, *A. versicolor*, *Mortierella alpina*, *Mucor circinelloides*, *M. hiemalis*, *M. mucedo*, *M. racemosus* *Penicillium brevicompactum*, *P. chrysogenum*, *P. cyclopium*, *P. expansum*, *P. funiculosum*, *P. glaucum*, *P.janthinellum* and *P. rubrum*) species were found in soils, and the remaining 30 species were found in both plants and soils.

In the next stage of the research, the antimicrobial activity of the products obtained from the studied plants (10% aqueous extract, alcoholic extract and essential oil) was evaluated. In this case, not classical test cultures, but fungi characterized by a wide diversity due to ecotrophic specialization and isolated from the soil during the research were used.

From soil samples exposed to anthropogenic impact, 50 pure cultures of micromycetes were isolated, differing in their cultural and morphological properties. This is evidenced by the data shown in Figure 1. The isolated pure cultures were classified as belonging to the following species: *A.alternata* (3 strains), *A. flavus* (2), *A. niger* (3), *Botrytis cinerea* (2), *Cladosporium herbarum* (3), *Fusarium oxysporum* (2), *F. verticillioides* (= *F. moniliforme*) (2), *Penicillium chrysogenum* (2), *P. cyclopium* (3), *Verticillium album* (2), etc. (26). Fungi isolated from the soil also differ from each other in the forms of manifestation of ecotrophic specialization (allergenic, toxigenic, opportunistic, phytopathogenic) and the nature of the pathologies they cause (hemibiotrophic, necrotrophic).

So that among the registered fungi, phytopathogens (*Alternaria alternata*, *Fusarium oxysporum*, *F. verticillioides*, *Verticillium album*), toxigenic species (*Alternaria alternata*, *Aspergillus flavus*, *A. niger*, *Fusarium oxysporum*, *F. verti-*

cillioides, *Penicillium chrysogenum*, *P. cyclopium*), as well as allergens and opportunistic forms were found. In general, it should be noted that some fungi, depending on the manifestations of ecotrophic specialization, can simultaneously belong to toxigenic, allergenic and opportunistic groups, for example, *A. niger*. Therefore, the use of such fungi as test cultures is of interest also from the point of view of developing future preventive measures to combat fungi with similar characteristics. At the final stage of the research was assessed the effectiveness of the influence of the products obtained from the studied plant species on the growth of fungal strains isolated from soils subjected to anthropogenic impact.

The efficiency of the process was determined by the yield of the resulting biomass (g/l) within 5 days after introducing a certain amount of the specified agents into the liquid Chapek medium. The obtained results showed that the products obtained from certain plants have the ability to exhibit antifungal activity against all the fungi studied, but the quantitative indicators of this activity differ significantly. In particular, the results of studies of the antifungal activity of 10% aqueous extracts of plants indicate that, although all plants contain water-soluble metabolites that have antifungal action to varying degrees, their activity is fungostatic in nature. That is, under their influence, the growth of all fungi is suppressed, and the degree of suppression, depending on the type of plant and fungus, is 21–67% (Table 2). Adding to the medium the same amount of the products obtained from the studied plants by extraction with 3% alcohol also has an effect on the growth of fungi, but overall the inhibitory effect is somewhat enhanced, and the degree of suppression is 28–71% (Table 3). It has been established that the addition of equal amounts of essential oils obtained from plants by hydrodistillation and calculated per unit of plant mass has a pronounced negative effect on the growth of fungi, and in some cases even was observed fungicidal activity. Thus, the addition of essential oils of plants into the nutrient medium resulted in a decrease in growth by 78–100% (Table 4).

Among the components obtained from plants, essential oils have higher antifungal activity, and this was observed in plants (*Allium rubellum*, *Mentha spicata*, *Poa bulbosa*) that have been almost unstudied in this direction in the studies conducted so far.

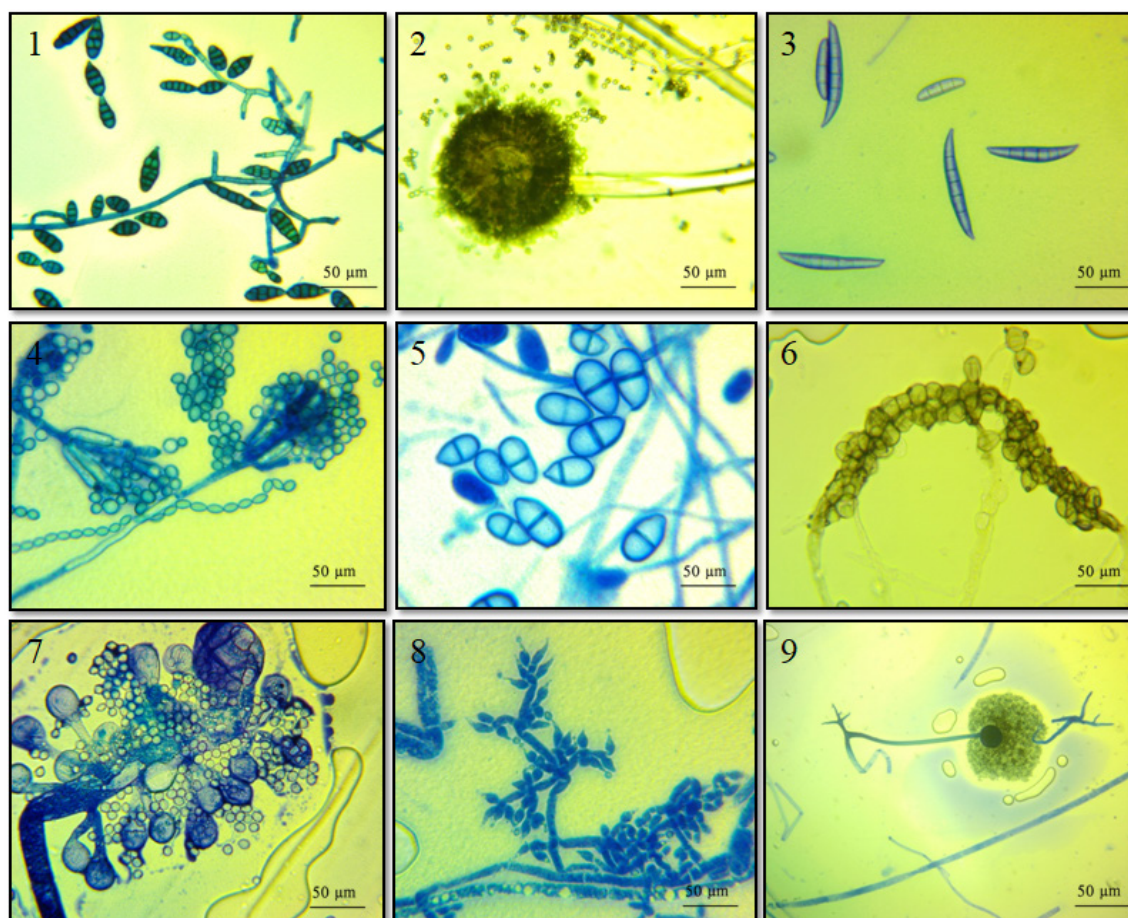


Figure 1 – Microscopic view of some structural elements of fungi such as *Alternaria alternata* (1), *Aspergillus niger* (2), *Fusarium oxysporum* (3), *Penicillium chrysogenum* (4), *Trichotechium roseum* (5), *Aureobasidium pullulans* (6), *Cunninghamella echinulata* (7), *Trichoderma asperellum* (8) and *Rhizopus stolonifera* recorded in studies.

Table 2 – General information on the effect of 10% aqueous extract from plants on the growth of fungi used as test cultures (amount of biomass produced relative to the control, in %).

№	Plant species Test-kultur										
		<i>Agropyrum repens</i>	<i>Mentha spicata</i>	<i>Calendula officinalis</i>	<i>Daucus carota</i>	<i>Alhagi pseudoalhagi</i>	<i>Rosa canina</i>	<i>Poa bulbosa</i>	<i>Trifolium pratense</i>	<i>Viola tricolor</i>	<i>Allium rubellum</i>
1	<i>Alternaria alternata</i>	61	42	51	61	54	55	47	57	50	39
2	<i>Aspergillus flavus</i>	63	45	55	58	53	55	45	52	52	41
3	<i>A.nidulans</i>	61	41	52	79	49	55	42	56	54	39
4	<i>A.niger</i>	58	50	53	65	51	53	43	56	54	39
5	<i>Botrytis cinerea</i>	57	48	55	68	50	50	41	51	50	39
6	<i>Cladosporium herbarium</i>	53	43	49	62	49	48	40	49	50	33
7	<i>Fusarium moniliforme</i>	50	44	51	63	51	50	46	55	52	39
8	<i>F.oxysporium</i>	51	42	49	61	52	56	42	50	55	37
9	<i>Penicillium chrysogenum</i>	56	47	54	52	55	57	49	57	57	40
10	<i>P.cuclopium</i>	54	44	53	58	52	55	46	52	58	39
11	<i>Trichoderma viride</i>	59	52	56	57	57	50	49	59	56	47
12	<i>Verticillium album</i>	52	48	54	60	54	51	48	50	51	42
Control		100									

Table 3 – General information on the effect of 3% alcohol extract from plants on the growth of fungi used as test cultures (in % relative to control).

№	Plant species Test-kultur	<i>Agropyrum</i>	<i>Mentha spicata</i>	<i>Calendula officinalis</i>	<i>Daucus carota</i>	<i>Alhagi pseudoalhagi</i>	<i>Rosa canina</i>	<i>Poa bulbosa</i>	<i>Trifolium pratense</i>	<i>Viola tricolor</i>	<i>Allium rubellum</i>
1	<i>Alternaria alternata</i>	61	42	51	61	54	55	39	57	50	38
2	<i>Aspergillus flavus</i>	63	45	55	58	53	55	40	52	52	39
3	<i>A.nidulans</i>	61	41	52	72	49	55	39	56	54	38
4	<i>A.niger</i>	58	50	53	59	51	53	42	56	54	40
5	<i>Botrytis cinerea</i>	57	48	55	68	50	50	39	51	50	40
6	<i>Cladosporium herbarium</i>	53	43	49	59	49	48	38	49	50	29
7	<i>Fusarium moniliforme</i>	50	44	51	61	51	50	47	55	52	31
8	<i>F.oxysporium</i>	51	42	49	62	52	56	39	50	55	34
9	<i>Penicillium chrysogenum</i>	56	47	54	56	55	57	42	57	57	39
10	<i>P.cuclopium</i>	54	44	53	54	52	55	41	52	58	38
11	<i>Trichoderma viride</i>	59	52	56	53	57	50	43	59	56	41
12	<i>Verticillium album</i>	52	48	54	59	54	51	44	50	51	39
Control		100									

Table 4 – General information on the effect of EO obtained from plants on the growth of fungi used as test cultures (in % relative to control).

№	Plant species Test-kultur	<i>Agropyrum repens</i>	<i>Mentha spicata</i>	<i>Calendula officinalis</i>	<i>Daucus carota</i>	<i>Alhagi pseudoalhagi</i>	<i>Rosa canina</i>	<i>Poa bulbosa</i>	<i>Trifolium pratense</i>	<i>Viola tricolor</i>	<i>Allium rubellum</i>
1	<i>Alternaria alternata</i>	5,1	1,5	1,3	14,1	3,8	13,7	0	3,4	3,3	0
2	<i>Aspergillus flavus</i>	5,2	2,4	2,5	13,7	4,0	14,1	9,3	5,5	5,0	0
3	<i>A.nidulans</i>	4,2	3,0	3,3	12,6	3,6	13,9	7,3	3,3	3,7	0
4	<i>A.niger</i>	5,0	3,0	3,2	11,8	3,5	9,8	6,6	3,6	3,7	0
5	<i>Botrytis cinerea</i>	2,9	0	2,5	10,7	3,0	9,1	4,2	3,0	2,8	0
6	<i>Cladosporium herbarium</i>	3,1	0	0	21,0	3,0	8,4	0	3,4	2,8	0
7	<i>Fusarium moniliforme</i>	2,9	2,0	1,8	14,9	3,3	8,2	5,7	3,5	3,5	0
8	<i>F.oxysporium</i>	4,0	1,9	2,7	13,6	4,0	7,6	0	3,2	3,2	0
9	<i>Penicillium chrysogenum</i>	2,9	1,9	2,3	17,5	3,5	9,8	0	3,8	2,9	0
10	<i>P.cuclopium</i>	4,2	2,2	2,5	15,4	3,2	8,1	2,1	3,1	3,5	0
11	<i>Trichoderma viride</i>	5,0	11,2	3,1	14,4	5,5	10,1	2,7	5,3	5,5	0
12	<i>Verticillium album</i>	3,2	0	1,7	12,5	3,0	11,1	0	3,0	2,8	0
Control		100									

4. DISCUSSION

There is growing interest in natural ingredients that contain substances that inhibit the growth of harmful microorganisms, primarily fungi, to one degree or another. These sources include plants, which are also of interest due to the presence of substances with biological, including pharmacological, activity in their composition [21]. This is confirmed by studies conducted in many countries [22-23], including the Republic of Azerbaijan [18, 24-26].

Typically, test cultures are used to determine various properties, including antibacterial, antifungal and other activities, in order to evaluate the field of application of a particular phytocomponent or metabolite, especially a phytocomponent intended for use in the food, feed and

medical industries. In this area, most studies use classical test cultures such as *Escherichia coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Candida albicans* [26]. In accordance with the development of science and technology, as new properties are discovered in fungi and bacteria, new approaches are also being developed in relation to test cultures, namely, cultures that differ in their characteristics from classical test cultures are increasingly being used. The main reason for this is the need to ensure the universality of the results obtained. Therefore, it has been deemed appropriate to use modern test cultures rather than classic ones in research.

Thus, it was shown that the components obtained from essential oil plants have both fungostatic and fungicidal ef-

fects on fungi. Among plants possessing this characteristic, the highest activity is observed in *Artemisia absinthium*, *A. vulgaris*, *Mentha piperita* and *Salvia officinalis*. For example, aqueous extracts from 10 essential plants inhibited fungal growth by 40-61%, alcoholic extracts by 44-68%, and essential oil by 100% [27].

Our study showed that some plant species belonging to the Azerbaijani flora contain plant components that partially or completely limit the growth of fungi with different forms of ecotrophic specialization (allergenic, toxigenic, opportunistic, phytopathogenic, etc.), even more than the above-mentioned plants. For example, aqueous and alcoholic extracts of *Allium rubellum*, *Mentha spicata*, and *Poa bulbosa* inhibited the growth of test fungi by 21-67% and 28-71%, respectively.

Furthermore, our study results showed that these plants provided habitat and nutrient media for certain fungi. Interestingly, there is a correlation between the abundance of fungal species involved in the mycobiota of a particular plant and its antifungal activity. Thus, a decrease in a plant's antifungal activity corresponds to a trend toward an increase in the number of fungal species comprising the mycobiota of a particular plant species. Clarifying this relationship for a wider range of plant species may also indicate that mycobiota abundance could be used in the future as an indicator of antifungal activity.

Moreover, future research should focus on identifying plants common in Azerbaijani conditions that possess high antifungal activity, particularly among plants that have not been studied or have been insufficiently studied. Thus, research conducted in many parts of the world focuses primarily on plants known to produce bioactive amines (BAS), and therefore the number of plant species studied in this area is limited. Therefore, a more appropriate approach in the future would be to focus more attention on less-studied plants. When conducting such research, it would be advisable to consider the interactions between plants and fungi, particularly endophytes, when exploring this issue. Even when penetrating plant cells, endophytic fungi do not harm them and the metabolites they synthesize are beneficial to plants and possess antifungal, antibacterial, antiviral, and other properties [28]. In our view, determining whether changes in the activity of a given plant's bioactive androgen systems (BAS) as a result of these interactions could be useful for the use of plants, as well as fungi, in this field.

5. CONCLUSION

Thus, the conducted studies have shown that some plants of the flora of Azerbaijan contain metabolites that are capable of suppressing the growth of fungi isolated from anthropogenically modified environments and possessing predominantly negative properties. However, the most effective are the essential oils obtained from these plants. This opens up broad prospects for their future use in the development of biopreparations designed for the preventive control of such fungi.

AUTHORS' CONTRIBUTIONS

B.K.F., M.P.Z. and N.R.Z. were the lead authors, having made major contributions to the conceptualiza-

tion, methodology, visualization, formal analysis, experimental design, and the writing—original draft as well as review and editing. Kh.D.T., S.S.A., İ.A.Kh., M.F.R., M.N.S., A.M.B. and J.S.İ - contributed significantly to the refinement of the manuscript through writing—review and editing, and participated in final draft development and interpretation of results, assisted with data curation and formal analysis, ensuring consistency and reliability of the experimental outcomes and participated in the laboratory experiment setup and contributed to the practical execution of growth and assay protocols. All authors have read and agreed to the publication of the final version of the manuscript.

ACKNOWLEDGEMENTS

Not applicable.

FUNDING

Not applicable.

CONFLICT OF INTEREST

There are no conflicts of interest to declare.

OPEN ACCESS

This article is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. To view a copy of this licence, visit <https://creativecommons.org/licenses/by-nc/4.0/>.

LITERATURE

1. Hudu S.A., Jimoh A.O., Amin-Nordin S., Syed Hassan S. Environmental degradation as a recipe for emerging viral diseases: implications for global health // One Health Outlook. – 2026. – Vol. 18; 8: 18. <https://doi.org/10.1186/s42522-026-00203-w>
2. Alotiby A. Immunology of Stress: A Review Article // Journal of Clinical Medicine. – 2024. – Vol.13(21), 6394. <https://doi.org/10.3390/jcm13216394>
3. Chaachouay N., Zidane L., Plant-Derived Natural Products: A Source for Drug Discovery and Development // Drugs Drug Candidates. – 2024. – Vol.3, – P. 184–207. <https://doi.org/10.3390/ddc3010011>
4. Nic L.E., Bachman S.P., Govaerts R. Plant states and fates: response to Pimm and Raven // Trends in Ecology & Evolution. – 2017. – Vol. 32(12). – P. 887–889. <https://doi.org/10.1016/j.tree.2017.09.005>
5. De Sousa D.P., Damasceno R.O.S., Amorati R. et al. Essential Oils: Chemistry and Pharmacological Activities // Biomolecules. – 2023. – Vol. 13(7): 1144. <https://doi.org/10.3390/biom13071144>
6. Fitzgerald M., Heinrich M., Booker A. Medicinal Plant Analysis: A Historical and Regional Discussion of Emergent Complex Techniques // Frontiers in Pharma-

cology. – 2020. – Vol. 10: 1480. <https://doi.org/10.3389/fphar.2019.01480>

7. Askerov A. Flora of Azerbaijan. – Baku. – 2016. – P. 444.

8. Kerimov Y., Isayev J., Suleymanov T. Modern directions of searching for promising wild plants of the flora of Azerbaijan and their use in pharmaceutical production // Journal of Pharmacy and Pharmacotherapy of Azerbaijan. – 2024. – Vol. 24. – P. 35–57. <https://doi.org/10.58495/CFMY7518>

9. Maheshwari R. Fungi: Experimental methods in biology (2nd ed.). CRC Press. – 2016. – P. 358.

10. Nevalainen H., Kautto L., Te'o J. Methods for Isolation and Cultivation of Filamentous Fungi // Methods in Molecular Biology. – 2014. – Vol. 1096. https://doi.org/10.1007/978-1-62703-712-9_1

11. Saba S., Iqra L., Asma A., Latif K., Khan S. et al. A laboratory manual of mycology. Scientific Knowledge Publisher (SciKnowPub). – 2024. <https://doi.org/10.5281/zenodo.10631334>

12. Balaji, A. Handbook of Plant Disease Identification and Management. – 2018. CRC Press, 620. <https://doi.org/10.1201/9780429504907>

13. Li D. W., Magyar D., Kendrick B. Color atlas of fungal spores: A laboratory identification guide. – 2023. ACGIH.

14. Seifert K.A. The genera of Hyphomycetes. Utrecht: CBS-KNAW Fungal Biodiversity Centre. – 2011. – P. 119–129. <https://doi.org/10.3767/003158511X617435>

15. Chauhan A., Jindal T. Microbiological Culture Media: Types, Role and Composition. In: Microbiological Methods for Environment, Food and Pharmaceutical Analysis. Springer, Cham. – 2020. – P. 23–66. https://doi.org/10.1007/978-3-030-52024-3_3

16. Kusuma H.S., Mahfud M. Retracted: Microwave hydrodistillation for extraction of essential oil from Pogostemon cablin Benth: Analysis and modelling of extraction kinetics // Journal of Applied Research on Medicinal and Aromatic Plants – 2017. – Vol. 4. – P. 46–54. <https://doi.org/10.1016/j.jarmap.2016.08.001>

17. Bakhshaliyeva K.F., Muradov P.Z., Ismayilova G.E., Namazov N.R., Jabrailzade S.M. Fungicidal activity of some medicinal plants of the flora of Azerbaijan // Modern Mycology in Russia. – 2017. – Vol. 6. –P. 208–209.

18. Muradov P. Z, Bakshaliyeva K. F, Gulahmedov S. G, Mammadova Y. M, Ismayilova G. E, Yusifova A. A. Influence of Aquatic Extracts and Essential Oils Obtained from Some Plants to the Growth of Toxigenic Fungi. // Biosci. Biotech. Res Asia. – 2023. – Vol. 20(1). – P. 223–228. <http://dx.doi.org/10.13005/bbra/3083>

19. Kurakov A.V. Methods for Isolating and Characterizing Complexes of Microscopic Fungi in Terrestrial Ecosystems. Moscow: MAKSPress. – 2001. – 91 p.

20. Welham S.J., Gezan S.A., Clark S.J., Mead A. Statistical Methods in Biology: Design and Analysis of Experiments and Regression (1st ed.). Chapman and Hall/CRC. – 2014. <https://doi.org/10.1201/b17336>

21. El-Saadony M.T., Saad A.M., Mohammed D.M., Korma S.A., Alshahrani M.Y. et al. Medicinal plants: bioactive compounds, biological activities, combating multi-drug-resistant microorganisms, and human health benefits - a comprehensive review//Front. Immunol. – 2025. –Vol. 16: 1491777. <https://doi.org/10.3389/fimmu.2025.1491777>

22. Amenu D., Desalegn R., Nugusa A. et al. Evaluation of antifungal activity of plant extracts against plant pathogen associated with sweet orange (*Citrus sinensis* L.), in Jimma, Western Ethiopia // Discov. Appl. Sci. – 2024. – Vol. 6(357). <https://doi.org/10.1007/s42452-024-06054-2>

23. Okla M. K., Alatar A. A., Al-amri S. S., Soufan W. H., Ahmad A., & Abdel-Maksoud M. A. Antibacterial and Antifungal Activity of the Extracts of Different Parts of *Avicennia marina* (Forssk.) Vierh // Plants. – 2021. Vol. 10(2): 252. <https://doi.org/10.3390/plants10020252>

24. Bakhshaliyeva K. F., Muradov P. Z., Ismayilova G. E., Naghiyeva S. E. and Mammadova M. Y. Mycobiota and Antifungal Activity of the Components of Some Medicinal Plants Spread in the Different Ecological Conditions // Advanced Studies in Biology. – 2023. – Vol. 15(1). P. 81–90. <https://doi.org/10.12988/asb.2023.91655>

25. Namazov N.R., Safarova A.Sh., Bakshaliyeva K.F., Muradov P.Z. Dependence Bactericidal and Fungicidal Activities from Component Composition of Essential Oils Obtained from some Essential Oil Plants // Int. J. Curr. Microbiol. App. Sci. – 2018. – Vol. 7(12). – P. 2406–2410. <https://doi.org/10.20546/ijcmas.2018.712.273>

26. Dubale S., Kebebe D., Zeynudin A., Abdissa N., Suleman S. Phytochemical Screening and Antimicrobial Activity Evaluation of Selected Medicinal Plants in Ethiopia // Journal of Experimental Pharmacology. – 2023. – Vol. 15. – P. 51–62. <https://doi.org/10.2147/JEP.S379805>

27. Mammadova M.Y. Extraction and application prospects of fungicidal compounds from certain essential oil plants // Abstract of the dissertation for the degree of Doctor of Philosophy // Baku –2025. – P. 37. <https://www.azmbi.az/PDF/seva/Meenglish.pdf>

28. Gao Y., Xu Y., Dong Z., Guo Y., Luo J., Wang F., Yan L., Zou X. Endophytic Fungal Diversity and Its Interaction Mechanism with Medicinal Plants // Molecules – 2025. – Vol. 30(5): 1028. <https://doi.org/10.3390/molecules30051028>