REPUBLIC OF AZERBAIJAN

On the rights of the manuscript

ABSTRACT

of the dissertation submitted for the scientific degree of
Doctor of Philosophy

THE MAIN FOREST-FORMING TREE SPECIES OF AZERBAIJAN AND THE ECOBIOLOGY OF THEIR PATHOGENIC MYCOBIOTA

Specialty:	2430.01 – Mycology
Field of science:	Biology
Applicant:	**Narmin Alibayli Suleyman**

BAKU – 2024

A certain part of the dissertation was carried out in the Azerbaijan State Pedagogical University, and other part in the laboratories of microbiological biotechnology and biologically active substances of the Institute of Microbiology the Ministry of Science and Education.

Scientific supervisor: Corresponding Member of ANAS
Panah Muradov Zulfigar

Official opponents: Doctor of Biological Sciences,
Professor
Khudaverdi Ganbarov Ganbar

PhD in Biology, Associate Professor
Afag Rzayeva Latifagha

PhD in Biology
Arzu Hasanova Rasul

Dissertation Council FD 1.07 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at the Institute of Microbiology of the Ministry of Science and Education of the Republic of Azerbaijan.

Chairman of the Dissertation Council: Doctor of Biological Sciences, Professor
Konul Bakhshaliyeva Farrukh

Scientific Secretary of the Dissertation Council: Doctor of Philosophy in Biology, Associate Professor
Gunel Gasimova Ali

Chairman of the scientific seminar: Doctor of Biological Sciences, Professor
Gular Seyidova Mirjafar

INTRODUCTION

Relevance and degree of the completion of the topic. Forests cover a certain part of the biosphere and play the main role in its development and protection. Not by chance, forests are called the lungs of our planet. Forests, characterized as a group of trees at first sight, may be characterized as a place where biological diversity is most widespread and active, just like soils. So all living forms of plants (trees, bush, grass), vertebrate and invertebrate animals, bacteria, fungi and viruses may be found in the forest. In short, forests are one of the places where species belonging to all taxonomic groups of living things on Earth, including "*fungi are common*"[1]. Currently, "*forests cover about 1/3 (32%) of the total land area of the planet*"[2].

"*Forests are unevenly distributed on the Earth*"[3] and the Azerbaijan Republic is among the countries with few forests in this distribution. So, currently "*the area of its territory covered by forest is about 1021.7 million hectares*"[4]. These forests have different features both pursuant to their distribution throughout the country and formations. Thus, 49% of the forests are located in the Greater Caucasus, 34% in the Lesser Caucasus, 2% in the Kura-Aras Lowland, 15% in the Talysh Mountains and the Lenkeran plain, and currently "*Azerbaijan is united by 18 forest formation*s"[5]. Generally, forests have an indispensable importance in preventing global environmental problems such as climate change, widespread desertification processes, reduction of biodiversity and disruption of

---

[1] Гусейнов, Э.С. Микромицеты основных лесообразующих пород Азербайджана и биология патогенных видов:/автореферат диссертации доктора биологический наук/-Москва, 1989, -48 с.

[2] ФАО и ЮНЕП. 2020 год. Состояние лесов мира – 2020. Леса, биоразнообразие и люди. Рим, ФАО. https://doi.org/10.4060/ca8642ru

[3] Звягинцев В.Б., Блинцов А.И., Козел А.В. и др. Защита леса. -Минск, -2019, -164 с.

[4] http://eco.gov.az/az/fealiyyet-istiqametleri/mesheler

[5] Məmmədov, Q.Ş. Azərbaycan meşələri/Q.Ş.Məmmədov, M.Y.Xəlilov. -Bakı: "Elm" nəşriyyatı, -2002, - 472 s.

the gas balance in the atmosphere, and this function of forests is becoming increasingly important.

The fact that the not-so-large territories of the Azerbaijan Republic have a variable and complex relief, trees and shrubs may spread up to 2000-2200 meters above sea level, has also led to the formation of a rich and colorful species diversity. Azerbaijan is known all over the world for its rich natural resources, colorful flora and fauna. *"About 5,000 species of higher plants belonging to 125 families and 930 genera are spread. Of these, 450 types of trees and shrubs belonging to 48 families and 135 genera grow in the country's forests. This is 70 regional endemic species in the dendroflora of Azerbaijan, up to 10% of the plant species in the country's flora. This makes up 1/6 of the total tree and shrub species. The forests of Azerbaijan consist mainly of broad-leaf species, but coniferous forests are also found"*[6,7,8]. For example, in the Lesser Caucasus, Goygol, the forests around the villages of Shamlig and Great Gishlag in the Tovuz region, in the forests of Gusar region in the Greater Caucasus, we may mention caucasian pine (pinus hamata).

Despite the differences in the division into different formations and distribution throughout the country, one feature of Azerbaijani forests remains constant, which concerns tree species covering a leading part in these forests. So "*up to 85% of trees in natural forests of Azerbaijan are oak (Quercus L.), beech (Fagus L.) and walnut (Parrotia)*"[9]. In other words, although Azerbaijan's dendroflora has a rich composition, the number of tree species forming the main forest is small.

Generally known, plants, including those growing in forests, are one of the main sources of nutrition for many living things, also fungi, and over the years *"various relationships have been formed*

[6] Əsgərov A.M. Azərbaycan ali bitkiləri (Azərbaycan florasının konspekti). // Bakı: Elm, 2008, III cild, 240 s.

[7] Məmmədov, T.S. Azərbaycanın nadir ağac və kol bitkiləri/T.S.Məmmədov, E.O.İsgəndər, T.H.Talıbov. -Bakı:Elm nəşriyyatı, -2014, -380 s.

[8] http://eco.gov.az/az

[9] http://eco.gov.az/az/fealiyyet-istiqametleri/mesheler

between fungi and plants"[10]. The relationship of fungi with forest components is so close that the transformation of the habitat leads to a change in the fungal biota and the xylemycobiota. As an ecological-trophic group, xylotrophic fungi (mushrooms) are typical and permanent inhabitants of forest ecosystems and play the main role in the cycle of substances formed, also the formation of humus, so play an indispensable role in the life of forests. Therefore, clarifying the distribution of xylotrophic fungi in forest ecosystems, the functions performed, the relationship among them and host-plants, etc. currently are one of the research directions of science fields such as botany, mycology, microbiology, ecology, etc. Currently, extensive research is conducted in this direction worldwide and a number of issues clarified, the functions performed via xylotrophic fungi in forest ecosystems specified pursuant to the requirements of the modern age.

Concerning the study of forest ecosystems and its fungal biota, *"Research has been conducted in Azerbaijan since the end of the 19th century"*[11] and the mycobiota of the trees typical of Azerbaijani nature is studied pursuant to the species composition, frequency of occurrence, ectrophic relations, the possibility of being used as a BAM (biologically active substances) producer (producens), etc. and "*these studies are still continued today*"[12,13,14]. In the studies in this direction, the main tree species of Azerbaijan forests were also researched pursuant to the species composition of

---

[10] Исаева, Л.Г. Болезни деревьев и кустарников Мурманской области// Грибные сообщества лесных экосистем. – М.; Петрозаводск: КарНЦ РАН, -2018. т. 5. -с. 48-56

[11] Axundov, T.M. Azərbaycanın mikobiotası/T.M.Axundov, B.B.Eyyubov, S.Y.Əhmədov. -Bakı: "Təhsil" nəşriyyatı, 2008, -352 s.

[12] Alıyeva, B.N. Azərbaycanın cənub bölgəsində yayılan ksilotrof makromisetlərin yeməli növlərinin biotexnoloji potensialı:/b.ü.f.d. dissertasiyanın avtoreferatı/-Bakı, 2021, -32 s.

[13] Baxşaliyeva, K.F. Azərbaycanın yayılan toksigen göbələklərin ekobioloji xüsusiyyətləri:/b.e.d. dissertasiyasının avtoreferatı/-Bakı, 2017, -43 s.

[14] Namazov, N.R. Azərbaycan florasına aid olan efiryağlı bitkilərin mikobiotası, onların tərkib elementlərinin bakterisid və fungisid aktivliyi:/b.e.d. dissertasiyasının avtoreferatı/ -Bakı, 2021, -64 s.

their mycobiota, but after the 70s-80s of the last century, their comprehensive study and the research of forests was carried out on the basis of the study of the general mycobiota, Diseases caused by fungi, especially xylotrophic macromycetes and anamorphs of bladder fungi playing the main role in forest ecosystems, and their prevalence were not provided due attention.

The aims and tasks. The aim of the work submitted is to study the species composition of the fungi involved in the formation of their mycobiota and the ecobiology of pathogenic species in the sample of some forests of Azerbaijan.

To realize the aim stated during the research, the following tasks are planned:

1. Determining the current status of individual species involved in the formation of some forests of Azerbaijan (on the territory of the Great Caucasus and Hirkan National Park);
2. Evaluating the xylomycobiota of some forests of Azerbaijan pursuant to species composition, ecology-trophic relationships and occurrence frequency;
3. Determining pathogenic species involved in the formation of the mycobiota of the main tree species of the forests studied and the prevalence degree of the pathologies caused by them;
4. Ecobiology of some fungal species involved in the formation of the pathocomplex of the main forest-forming tree species of Azerbaijan.

Research methods. The research was mainly performed on the basis of observations and analysis of the samples taken in the forests of the Great Caucasus and Hyrkan National Park of the Azerbaijan Republic. Observations and sampling were carried out pursuant to the methods of choosing a planned route and permanent stationary areas accepted in both botany and mycology. Clarification of the issues such as on-site passport of mushroom samples collected, analysis in the laboratory, identification of the disease and its causative agents was carried out based on the methods and approaches widely used in botany, mycology and phytopathology. To reach quantitative results, experiments were repeated at least 4 times, the findings processed statistically, and

indicators providing the conditions of honesty ($m/M = P \leq 0.05$) included in the thesis (dissertation).

The main provisions of the dissertation submitted for defense.

1. Although the main types of trees forming a forest in the forest ecosystems studied are the same, the specific weight of their distribution in a particular forest may vary depending on the natural climatic conditions of the area and the impact of anthropogenic load;
2. The relatively high specific weight of the number of pathogenic species among the fungi observed in the trees spreading in this or that forest is about that the trees are a favorable source of food and a place of residence for fungi;
3. The number of pathologies observed in forests is not related to the number of species involved in its occurrence, but mainly to the ecotrophic features of these species;
4. The presence of certain differences in the morphology of the spores and fruit bodies during the observation period of the disease is the basis of the changes in the development cycles of the pathological agents accompanying the trees.

Scientific novelty of the research. As a result of the research, the forests located in the Great Caucasus and Hirkn National Park of the Azerbaijan Republic were studied pursuant to the main tree species, the species composition of the mycobiota of those trees, and the ecobiology of pathogenic species. Turned out that 79.85% of every 100 trees in the forests researched are Oriental beech, Hornbeam and Chestnut-leaved Oak. 12.92% of poplar, small-leaved linden, Persian Ironwood, linden, European ash are distributed in those forests, and 7.23% are other (various fruit trees, conifer trees).

Determined that although the area of the territories taken for tree counting in both BQ and HMP is the same, different numbers of separate trees, beech and oak are represented in the HMP, and hornbeam in greater numbers per unit area in the forests located in the BQ. It is more logical to relate the reason for this to the natural climatic conditions of the areas and the anthropogenic impact load

on the forests, the biological sustainability indicators.

Turned out that all the trees involved in the formation of the forests studied are also one of the habitats and feeding places of fungi, 87 species were determined to be involved in the formation of the mycobiota of the forest trees studied. Determined that 76 types of fungi have some degree of pathological activity.

Determined that, among the fungi recorded, species such as *Conostroma gurcicola* Westend, *Hysterographium fraxini* (Pers.) De Not and *Pseudocercosporella fraxini* (Ellis & Kellem) U. Brown are the first to be distributed in Azerbaijan nature, 6 species are capable of causing powdery mildew, 2 to rust, 25 to spot and 43 to rot. Among these fungi, there are species with and without substrate specificity, but the specific weight of universal species constitutes the greater part of the total mycobiota.

During the evaluation of the forests studied for powdery mildew, rust, spotting and rotting diseases, revealed that the most widespread disease is spotting, which accounts for 55.1% of all diseases recorded in the research. Of the remaining recorded diseases, 2.3% belong to powdery mildew, 0.7% to rust and 41.8% to rot diseases.

Determined that in the plants studied, different changes are observed in the development cycles of fungi causing various pathologies depending on the local climate conditions, and this clearly manifests itself in the morphology of the spores and fruit bodies during the observation period of the disease.

Theoretical and practical significance of research. The obtained in the thesis is the actual material that expands the perception of the modern status of the participation of trees in forest formation in Azerbaijani forest ecosystems and the species composition of their mycobiota.

The information obtained on the biology of the development of pathogenic mycobiota of the main trees involved in forest formation is a theoretical and practical basis for the preparation of preventive measures against tree diseases spreading in the conditions of Azerbaijan.

The results obtained are also useful as the base data for the

new system, necessary for preparing the proposed 3-point evaluation system based on the implementation of complex (botanical, mycological, phytopathological, entomological, forestry, ecological, etc.) research in the future, considering the pathological processes in the assessment of forests in Azerbaijan.

Publication, approbation and application of the dissertation. A total of 10 works about the dissertation (thesis) were published. The thesis materials were reported at the scientific and practical conference on "Modern problems of biology" (Baku, 2019), at the XXXI International scientific-practical conference on "Development trends of modern science" (Canada, Vancouver, 2021), at the Republican scientific conference on "New trends and innovations: development prospects of microbiology in Azerbaijan" (Baku, 2022).

The organization where the thesis was done. The main part of the dissertation was performed at the Faculty of Biology and Chemistry of the Azerbaijan State Pedagogical University, other part in the laboratory of phytopathogenic microorganisms and biological control of the Institute of Microbiology of the Ministry of Science and Education of the Azerbaijan Republic.

The structure and scope of the thesis. The dissertation consists of a total of 162 computer pages and make up a total of 222.700 signs.

CHAPTER I.
THE MAIN TREE SPECIES AND PATHOGENIC SPECIES OF THEIR MYCOBIOTA INVOLVED IN THE FORMATION OF AZERBAIJAN'S FORESTS

In the 1.1st section of the thesis, literature data on Azerbaijani forests, their general features and the main tree species forming the forest are analyzed.

In the 1.2nd section of the dissertation, the results of research on the study of the mycobiota of forests, Azerbaijani forests, are analyzed, also pathogenic species and learning levels are evaluated.

CHAPTER II.
RESEARCH MATERIALS AND METHODS

2.1. General features of the areas researched

Research was conducted in the forests of the Greater Caucasus and Talysh Mountains of the Azerbaijan Republic between 2017 and 2021 (Figure 1), and these areas differed for of forest area.

Figure 1. View of the areas researched against the background of the of the Azerbaijan Republic territory

Thus, forests cover larger areas in the Greater Caucasus. The forests located in the area mentioned are not only related to the size of the area, but also are similar (soil types, temperature indicators, climate types, precipitation amount) and different (tree species forming the main forest, the richness of its flora and fauna) from each other pursuant to a number of indicators.

2.2. The methods used for analysis in the studies

The methods of *"planned route and selection of permanent areas for stationary observations"*, widely used in the course of mycological studies, were also applied in the collection of fruiting bodies of xylotrophic macromycetes.[15] Sampling was mainly carried out twice a year - in May-June and September-October.

Both micromycetes and macromycetes were sampled from shoot system of the plants, and passport process on-site was done during sampling. More specifically, information about the name of the plant from the sample taken, the name of the plant organ from the sample taken, the biological status of the plant, etc. and the samples are collected in specially designed sterile paper bags. The samples collected in packages are stored in special portable refrigerators until they are brought to the laboratory.

Both the identification of the fruit bodies taken from the researched areas and brought to the laboratory, getting pure cultures were carried out, at this point, *"known methods"*,[16,17], various *"specifiers"*[18,19,20], were applied during identification, and *"information provided on the official website of the BMA"*[21] used in naming the mushrooms.

During the determination of the main tree species of the forests, a 50x50m area is taken in different parts of the forests

---

[15] Томашевич, М.А. Формирование патокомплексов растениц при интродукции в Сибири:/диссертации д.б.н./-Новосибириск, 2015, -с. 462

[16] Малый практикум по ботанике. Водоросли и грибы / Т. Н. Барсукова, Г. А. Белякова и др. -М.: Издательский центр «Академия», -2005. - 240 с.

[17] Методы экспериментальной микологии/Под. ред. Билай В.И. Киев: Наукова думка, -1982, -500 с.

[18] Бондарцева, М.А. Определитель грибов России. Порядок Афиллофоровые. Вып. 2./М.А.Бондарцева. -СПб.: Наука, -1998. -391 с.

[19] Horst, K. R. Westcott's Plant Disease Handbook. Eighth Edition. -New York: Springer Science, -2013, -826 с.

[20] Kirk, P. M. Dictionary of the fungi, 10th edn. CABI publishing / P. M. Kirk, J.A. Stalpers, P. F. Cannon.– Wallingford(UK), -2008, -600 p.

[21] https://www.mycobank.org

located in a specific area and the trees are counted. At least 4 plots are taken for each forest and an average number is found pursuant to the total number of trees counted.

During the examination of the microscopic symptoms of mushrooms, a microscope with a magnification of up to 2500 times, "OMAX 40X-2500X LED Digital Laboratory Trinocular Compound Microscope with USB Camera" brand is used.

The occurrence frequency (RT) (or spread rate) of fungi (or diseases caused by them) on separate trees was calculated pursuant to the formula N=(a/A)•100, so N – RT (prevalence rate, %), A- total number of trees counted in the area (number), a- the number of trees where the fungus (disease) was detected (number).

When obtaining quantitative results, all experiments were performed in at least 4 replicates, and the results obtained were *"statistically processed"*[22] and the information, which integrity isnt in doubt, was included in the thesis (dissertation).

CHAPTER III.
GENERAL CHARACTERISTICS OF THE MAIN TREES INVOLVED IN THE FORMATION OF AZERBAIJANI FORESTS PURSUANT TO THEIR SPECIES COMPOSITION

3.1. General characteristics of Azerbaijani forests and the trees involved in their formation pursuant to their species composition and density

During the studies, when determining the number of trees both in the territory of the Hirkan National Park and in separate forest areas in the Greater Caucasus, turned out that 79.3% of every 100 trees in the HMP and 80.4% on average in the Greater Caucasus are beech, hornbeam and oak, i.e. the average indicator

[22] Кочетов А.Г., Лянг О.В., Масенко В.П. и др. Методы статистической обработки медицинских данных: Методические рекомендации для ординаторов и аспирантов медицинских учебных заведений, научных работников. -М.: РКНПК, -2012. -42 с.

for both forest ecosystems is 79.9%. The remaining 20.1% of trees belong to ironwood, linden, cottonwood, european ash, various wild fruit trees (apple, greengage, cranberry, etc.).

Although the area of the territory taken for tree counting is the same in both places, noted that separate trees have different numbers, and beech and oak are represented in greater numbers in the HMP, and hornbeam in the forests located in the Greater Caucasus, in our opinion, it would be more logical for seeking the reason in the difference in the anthropogenic impact load of forests in the Greater Caucasus and HMP.

3.2. Evaluation of the mycobiota of the main tree species of the forests studied pursuant to species composition

As a result of the analysis of the samples taken from the plants selected as the main trees forming the forest, turned out that a total of 87 species of fungi are involved in the formation of the mycobiota of the plants mentioned (Table 1). Apparently, all recorded fungi belong to true fungi (Mycota or Fungi), namely 3 species belong to *Mucomycota*, 38 species to *Ascomycota*, and 46 species to *Basidiomycota*. The number of genera species recorded in the studies varies from 1 to 6, and the highest indicator belongs to the species of the genus Phellinus. Generally, the number of species of fungi recorded between 1-3 is 70.1% of the total fungi, and the species represented by 4 and more are 29.9%. It may also be noted as an indicator that they play a different role in the ecological functions performing in the forests studied.

Among the fungi registered, there are both true biotrophs, true saprotrophs, and those whose biotrophy and saprotrophy are not true, that is, facultatives. About the fungi recorded pursuant to the type of decay caused, those causing white, brown, mixed, and soft rot are observed. These decay types are all known to science currently, that is, the fungi recorded represent all decay types. A similar point may be made about the hyphal system of fungi, as they include species with monomyotic, dimitic and trimitic hyphal systems.

Table 1

General characteristics of fungal species recorded in the main tree species involved in the formation of some forests of Azerbaijan

1	Mucormycota	Ascomycota	Bazidiomycota
Those with species number between 1-3	*Mucor(2) Rhisopus(*1)	*Ascochyta(2), Alternaria*(1), *Cercospora(2), Clithris(1), Conostroma(1), Cylindrocarpon(1), Cytospora(1) Erysiphe(2)*, ***Hysterographium****(1) Marssonina(1), Microsphaera(1), Mycosphaerella(1), Naemospora(1), Nectria(1), Phyllactinia(1), Septoria(3) Stigmina(1), Taphrina(1), Verticillium (1), Uncinula(1)*	*Abortiporus(1), Armillaria(1), Bjerkandera(2), Cerrena (1), Climacodon (1) , Daedalea (1), Daedaleopsis (1), Fomes(1), Fuscoporia (1), Ganoderma (3), Laetiporus (1), Lentinus (1), Lenzites(1), Melampsora (2), Panus(1), Phaeolus(1), Pholiota (1), Pleurotus (1), Poyporus (2), Porodaedalea (1), Pycnoporus (1), Schizophyllum (1) Spongipellis(1), Stereum(2), Trametopsis(1), Trichaptum(1), Vuilleminia(1)*
Those with species number ≥4		*Penicillium(4) Gloeosporium (4)*	*Fomitopsis(4) İnonotus(4) Phellinus(6) Trametes(4)*
Total share (%)	3,8	31,6	64,6

Note that fungi play a different role not only in forests, but also in the life of individual trees. This is also confirmed by the fact that the number of fungal species involved in the formation of the mycobiota of each tree is different, and participating in different combinations (Figure 2). Noticeably, common poplar is richer among the trees studied, while european ash and ironwood are characterized by the lowest mycobiota. Interestingly, although the number of species involved in the formation of the mycobiota of one or another tree in separate forests differs slightly, the ranking of trees in both forests by the number of mycobiota remains unchanged.

Table 2

Quantitative characterization of fungal species participating in the mycobiota of the trees studied

№	Tree species	The number of fungal species recorded, number (share in the total mycobiota, %)		
		Greater Caucasus	HMP	Total
1	Hornbeam (Carpinus betulus)	34(47,2)	38(50,7)	40(52,6)
2	Oriental beech (fagus orientalis)	31(43,1)	33(44,0)	34(44,7)
3	Chestnut-leaved Oak (quercus castaneifolia)	30 (41,7)	30(40,0)	32(42,1)
4	Poplar (Populus)	43 (59,7)	46(61,3)	47(61,8)
5	Littleleaf Linden (tilia cordata)	27 (37,5)	26(34,5)	29(38,2)
6	Ironwood (parrotia persica)	-	17(22,7)	17(22,4)
7	European ash (Fraxinus excelsior)	15(20,8)	16(21,3)	17(22,4)
8	Others (various fruit trees, conifers, etc.)	27(37,5)	30(40,0)	35(46,1)
Sum		65(100)	70(100)	87(100)

Apparently, there is a difference in the distribution of the 76 species recorded in the studies in different forests, and the number of species involved in the formation of the mycobiota of the trees spreading to the HMP is greater. When calculating the Sorensen similarity coefficient of the fungal species distributed in these two forest ecosystems, turns out that this number is 74.4.

About the fungi recorded, 16 were found to be distributed only on a plant, i.e. they are species with substrate specificity pursuant to the results of these studies (Fig. 3). Clearly, specific species are found in all tree species studied, but their number is different and the maximum number of fungi characterized from this aspect, i.e. 5 species, is found in chestnut-leaved oak (HPM). The number of such species in european ash and poplar is equal to 3 (HPM).

3.3. The list annotated of fungi recorded in the studies

As noted in the previous section of the study, determined that 87 species of fungi are involved in the formation of the mycobiota of the main trees of the forests located in the Greater Caucasus and the southern part of Azerbaijan. This was the result of research conducted in the mentioned forests in 2016-2022. Generally, a descriptive list of plant and fungal species recorded in both botanical and mycological studies is also drawn up, so we considered it appropriate to apply it during the research. The relevant information about the trees chosen as one of the main research objects in the studies is given above, so the information about fungi is included here. The list of fungi is provided in alphabetical order due to the order of development pursuant to separate large taxon (sections), but a single ranking.

There is no universally accepted approach to compiling the list of fungi annotated, so the elements of individuality are also observed in each author's approach to this task.

Table 3

General characteristics of the mycobiota of tree species involved in the formation of some forests of Azerbaijan

№	Tree species, number (%)	Greater Caucasus	HMP
1	Hornbeam (Carpinus betulus)	*Gloeosporium carpini*	*Gloeosporium carpini*
2	Oriental beech (fagus orientalis)	*Ascochyta fagi*	*Ascochyta fagi*
3	Chestnut-leaved Oak (quercus castaneifolia)	*Ascochyta quercus Clithris quercina Daedalea quercina Gloeosporium quercinum*	*Ascochyta quercus Clithris quercina Cytospora quercela Daedalea quercina Gloeosporium quercinum*
4	Poplar (Populus)	*Marssonina populi Phyllosticta populina Septoria populi*	*Marssonina populi Phyllosticta populina Septoria populi*
5	Linden (tilia)	*Septoria tilia*	*Septoria tilia*
6	Ironwood (parrotia persica)	*Fuscoporia torulosa*	*Fuscoporia torulosa*
7	European ash (Fraxinus excelsior)	*Cercospora fraxini Hysterographium fraxini Uncinula fraxini*	*Hysterographium fraxini Uncinula fraxini*
8	Others	*Phellinus tuberculosus Stereum sanguinolentum*	*Phellinus tuberculosus Stereum sanguinolentum*
Total:		16	16

Considering this, summarizing the approaches used in the work of various authors, it was considered appropriate for compiling information about the name of the mushroom specified in writing the thesis, the number of synonyms, the name of the substrate on which the mushroom was first recorded during the research, its ecotrophic relations and distribution in the world and Azerbaijan in the list annotated of the mushrooms recorded.

CHAPTER IV.
ECOBIOLOGICAL FEATURES OF PATHOGENIC SPECIES OF FUNGI INVOLVED IN THE FORMATION OF THE MYCOBIOTA OF THE MAIN TREE SPECIES OF THE FORESTS IN THE AZERBAIJAN REPUBLIC

4.1. General characteristics of diseases caused by pathogenic species of fungi

Noted that the wood-inhabiting fungi are divided into two parts in relation to the host plant. Thus, the first are epiphytic, and the second are pathogenic mycobiota. Pursuant to the purpose of our research, after this phase, we focused our attention on the fungal species involved in the formation of pathogenic mycobiota. It was considered appropriate to systematize the fungi causing the diseases observed in the trees studied due to the following division:

1. Powdery mildew agents
2. Rust causing agents
3. Spotting agents
4. Agents of decay (deterioration)

When characterizing based on the distribution mentioned, turns out that among the fungi recorded, the number of decay-causing fungi is higher than the others, and the number of rust-causing fungi is smaller (Figure 4).

Table 4

Characteristics of the fungi recorded in the studies due to the diseases caused

№	The name of diseases	Name (number) of relevant disease-causing species
1	Powdery mildew (floury dew)	*Erysiphe(2)*, *Microsphaera(1), Phyllactinia(1), Taphrina(1)* and *Uncinula(1)*
2	Rust	*Melampsora (2)*
3	Spotting	*Ascochyta(2), Alternaria(1), Cercospora(2), Clithris(1), Conostroma(1), Cylindrocarpon(1), Cytospora(1) , Gloeosporium (4) Hysterographium(1), Marssonina(1), Mycosphaerella(1), Naemospora(1), Nectria(1), Phyllosticta(1), Penicillium(2) Septoria(3) Stigmina(1)* and *Trichotecum(1)*
4	Decay	*Abortiporus(1), Armillaria(1), Bjerkandera(1), Cerrena (1), Climacodon (1), Daedalea (1), Daedaleopsis (1), Fomes(1), Fomitopsis(4) Fuscoporia (1), Ganoderma (3), İnonotus(4) Laetiporus (1), Lentinus (1), Lenzites(1), Panus(1), Phaeolus(1), Phellinus(5) , Pholiota (1), Pleurotus (1), Polyporus (2), Porodaedalea (1), Pycnoporus (1) Schizophyllum (1) Spongipellis(1), Stereum(2), Trametopsis(1), Trichaptum(1)* and *Vuilleminia(1)*

Noticeably, 76 of the 87 species recorded in the studies are involved in the occurrence of one or another pathology, i.e., 87.4% of the fungi registered are pathogenic.

4.2. The degree of spread of diseases caused by pathogenic species and the development features of agents

Turned out from the research conducted on the prevalence of pathogens in different groups tha all the fungi characterized as powdery mildew belong to the order Erysiphales of the division Ascomycota and the main characteristic feature of these disease-causing fungi is inhabiting only on living trees, mainly on their leaves, and having a pouch phase, i.e., they belong to telemorphs.

Generally, noted that powdery mildew pathogens arent characterized by a wide variety of species in the trees studied, and their prevalence isnt very high, so, during the research, the disease caused by fungi corresponding to this category is encountered a total of 73 times during the studies, i.e., it accounts for 2.3% of the trees (3.142 trees) carrying the pathology recorded in the course of research (Table 5).

Table 5

Prevalence of powdery mildew pathogens involved in the mycobiota of the trees studied

№	Tree species	The number of recorded mushroom species, number (total share, %)		
		Greater Caucasus	HMP	Total
1	Hornbeam	2(2,7)	3(4,1)	5(6,8)
2	Oriental beech	6(8,2)	7 (9,6)	13(16,4)
3	Chestnut-leaved oak	5(6,9)	6(8,2)	11(16,4)
4	Poplar	8(11,0)	9 (12,3)	17(21,9)
5	Littleleaf Linden	2(2,7)	3(4,1)	5(6,8)
6	Ironwood	-	-	0
7	European ash	-	-	0
8	Others	11(15,1)	11(16,4)	22(31,5)
Sum		34(46,6)	39 (53,4)	73(100)

Clearly, there is no significant difference in the prevalence of the disease over the study areas, and in both cases the disease is

most common on poplar.

As noted, the second group of causative agents of the disease consists of rust fungi, and during the research, the spread of 2 types of causative agents of this disease are detected. Species such as Melampsora pinitorqua and Melampsora populina were detected to spread to these fungi with a biotrophic lifestyle and relatively limited substrate specificity. Their host plants were mainly oak and poplar. Generally, the disease caused by these fungi was detected 23 times during the research, and their distribution pursuant to the host plant was as follows (Figure 6). Clearly, poplar is the most common type of rust disease.

Table 6

The prevalence degree of rust disease agents involved in the mycobiota of the trees studied

№	Tree species	The number of mushroom species recorded, number (total share, %)		
		Greater Caucasus	HMP	Total
1	Chestnut-leaved oak	3(13,1)	4(22,6)	7(30,5)
2	Poplar	5(21,8)	6 (33,9)	11(47,8)
3	Others	2(8,7)	3(17,0)	5(21,7)
Sum		10 (43,5)	13 (56,5)	23(100)

Spotting disease agents are more widespread than both powdery mildew and rust fungi in the plants studied, as noted, 27 species of fungi recorded are involved in the occurrence of this type of disease, more precisely, the spotted disease, similar in appearance but differs in color (black, brown, gray, etc.), and this disease is found in all the trees studied (Figure 7). Clearly, most of the species involved in the occurrence of the disease are found in poplar, and the least in ironwood. As for the specific weight of the spotted disease in the number of pathologies registered, in this case, the trend observed with the number of fungal species is generally maintained. So, 1732 of the 3142 registered pathology-carrying

trees have spotting disease, which is 55.1%. It may be appropriate to make a point about the fungi causing the spotting disease related to the taxonomic and eco-trophic relations of the fungi causing this disease.

Table 7

Prevalence rate of spotting disease agents involved in the mycobiota of the trees studied

№	Tree species	The number of mushroom species recorded, number		
		Greater Caucasus	HMP	Total
1	Hornbeam	124	134	258
2	Oriental beech	115	116	131
3	Chestnut-leaved oak	133	126	159
4	Poplar	156	153	309
5	Littleleaf Linden	110	106	216
6	Ironwood	0	65	65
7	European ash	76	75	151
8	Others	118	125	143
Sum		832	900	1732

Thus, most of the fungi causing spotting disease, more precisely, those registered during the research, 21 species taxonomically belong to the anamorphs of Ascomycota division, and 3 species to the telemorphs. Conversely, all fungi recorded belong to facultatives in terms of ecotrophic relations, i.e. those without saprotrophy and biotrophy.

Although the number of species is less than those causing rotting diseases, it is due to these features that more than half of the trees with pathology fall into them.

As noted, the number of fungal species causing rot in the forests studied is equal to 43, and the distribution of pathologies caused is different among separate trees (Figure 8). Apparently,

common poplar is the most common type of rotting disease, and 21 species of fungi involved in the formation of its mycobiota may cause white or brown rotting disease.

Table 8

General characteristics of the distribution of decay-causing fungi on the trees studied

№	Tree species	The number of mushroom species recorded, number		
		Greater Caucasus	HMP	Total
1	Hornbeam	96	98	194
2	Oriental beech	99	95	194
3	Chestnut-leaved oak	91	89	180
4	Poplar	112	114	126
5	Littleleaf Linden	85	90	175
6	Ironwood	0	32	32
7	European ash	66	73	139
8	Others	84	90	174
Sum		633	681	1314

Generally, 1314 of 3142 pathologies caused by any fungus are attributed to these fungi. Although the species number of causative agents of spotting disease is relatively little, the number of pathologies caused is greater than those causing decay diseases (Figure 9). We think that the reason is that the vast majority of fungi causing rot, especially white and brown rotting, belong to xylotrophic macromycetes and their habitat is only trees and mostly in tree trunks.

Table 9

General characteristics of the distribution of pathologies for the trees studied

№	Tree species	The number of pathologies recorded, number (%)		
		Greater Caucasus	HMP	Total
1	Powdery mildew	34	39	73
2	Rust	10	13	23
3	Spotting	832	900	1732
4	Rotting	633	581	1314
Sum		1509	1633	3142

The fungi causing spotting disease may inhabit in all shoot system of plants and show their pathological features.

FINAL ANALYSIS OF RESEARCH RESULTS

Despite the rich and colorful nature of the Azerbaijan Republic, it is included in the list of countries with the least forests in the world, and currently *"11.4% of its territory is covered with forests"*[23], but in the early 21st century, the area of these forests was much larger. Indeed, this trend is characteristic not only for the Republic of Azerbaijan, but also for the world, so that thousands of hectares of forests are destroyed every year in the world, and even now *"it is characterized as a global problem"*[24]. Considering the *"problems"*[25] caused by global climate change, then it should be

[23] http://eco.gov.az/az/fealiyyet-istiqametleri/mesheler

[24] Sandker, M. Finegold Y., D'annunzio R. et al. Global deforestation patterns: comparing recent and past forest loss processes through a spatially explicit analysis //The International Forestry Review, -2017, v. 19, № 3. -p. 350-368

[25] Ali, A., Riaz, S., Iqbal, Sh. Deforestation and its Impacts on Climate Change an Overview of Pakistan//Papers on Global Change, -2014, v.21, -p. 51-60

considered an indisputable reality to be more careful with forests, to adhere to the principles of sustainable development in their use.

The trees involved in the formation of any forest differ due to their species composition, density of their location in the forest, etc., and these differences are widely used during the characterization of forests. However, the functions of forests, regardless of their type, species composition, etc., are of vital importance for ensuring the sustainability of the biosphere, and its protection, proper management of its use are the tasks of the modern era.

Considering all noted, it was considered appropriate for studying some forests in Azerbaijan in the aspect mentioned, i.e. the main trees involved in its formation and the factors influencing the biological activity of those trees.

Pursuant to the mentioned, considered appropriate to conduct research in the forests of the BG and TD areas of Azerbaijan (also Lankaran plain) as a forest ecosystem. So, the forests in the territory of the Azerbaijan Republic and, in a sense, the natural soil and climate conditions of the territory, these forests have a relatively different variety, and their territory constitutes 64% of the forest stock specific to Azerbaijan.

As a result of the research conducted in the forests located in BQ and HMP, chosen as the research object, determined that the density of the main tree species forming the forest is different, and in those forests, on average, 79.85% of every 100 trees are Oriental beech, Hornbeam, and Chestnut-leaved Oak. In those forests, the share of Aspen, Littleleaf Linden, Ironwood and European ash is 12.92%, and the rest share (various fruit trees, conifer trees, etc.) is 7.23%.

Turned out that all the trees involved in the formation of the forests studied are also one of the habitats and feeding places of fungi, 87 species are determined to be involved in the formation of the mycobiota of the studied forest trees. Determined that 76 types of fungi recorded have some degree of pathological activity, and species such as Conostroma gurcicola Westend, Hysterographium fraxini (Pers.) De Not and Pseudocercosporella fraxini (Ellis & Kellem) U. Brown were detected for the first time to spread in the

nature of Azerbaijan. On the one hand, although this fact is important for the expansion of the mycobiota characteristic of the nature of Azerbaijan, on the other hand, it is the basis for the non-comprehensive study of the mycobiota characteristic of the Azerbaijan nature and for future research in this direction.

Finally, based on the results obtained in the studies, it would be appropriate to mention a point about functional diversity (FM). It is a component of biodiversity including a number of functional characteristics of the microorganisms making up the majority of the ecosystem, and FM with great ecological importance, has the ability to affect various aspects of the functioning of that ecosystem (ecosystem dynamics, stability, nutrient supply, etc.). Its measurement may be carried out due to functional richness and evenness, the first reflects the richness of the species with a particular sign, and the second represents the even distribution of species. Naturally, *"their reduction leads to a decrease in productivity and stability of the ecosystem"*[26]. So, based on the evaluation of these issues, it is possible to model the effect of functional diversity on ecosystem productivity and determine the direction of changes in the ecosystem. If we evaluate the research on the forest ecosystem in the Republic of Azerbaijan for this aspect, turns out that there is no research material for clarifying this issue, namely FM. Therefore, future research in forests must be conducted in this regard and should be an important task for evaluating the status of forest ecosystems, more precisely, their stability and productivity as an ecosystem. A similar point may be made based on the studies conducted by evaluating the main tree species making up the forest due to their biological sustainability and viability. So, there is no literature information on recent research in our forests on this subject.

[26] Goswami M., Bhattacharyya P., Mukherjee I. et al. Functional Diversity: An Important Measure of Ecosystem Functioning// Advances in Microbiology, - 2017, v.7. -p. 82-93.

CONCLUSIONS

1. As a result of the research in the forests spread in different areas of Azerbaijan (Greater Caucasus-BQ and Hirkan National Park-HMP), determined that in those forests, on average, 79.85% of every 100 trees are Oriental beech, Hornbeam and Chestnut-leaved Oak. Poplar, Littleleaf Linden, Ironwood, Common linden, and European ash spread in those forests account for 12.92%, and the rest share (various fruit trees, conifer trees, etc.) is 7.23%.
2. Determined that even though the area of the territories taken for tree counting in both BQ and HMP is the same, having different numbers of separate trees, beech and oak are more abundant in a single area in HMP and SW forests. It is more logical to relate the reason with the natural climatic conditions of the areas, the anthropogenic impact load in the forests, and the biological sustainability of separate trees.
3. Turned out that all the trees involved in the formation of the forests studied were also one of the habitats and feeding places of the fungi, 87 species were determined to be involved in the formation of the mycobiota of the forest trees studied. The 76 species of fungi recorded were found to have some degree of pathological activity, and species such as Conostroma gurcicola Westend, Hysterographium fraxini (Pers.) De Not and Pseudocercosporella fraxini (Ellis & Kellem) U. Brown were defined for the first time to be widespread in the nature of Azerbaijan.
4. Determined that 6 types of fungi recorded may cause powdery mildew, 2 types of rust, 25 types of spotting and 43 types of rotting diseases. Among these fungi, there are species with and without substrate specificity, but the specific weight of universal species constitutes the greater part of the total mycobiota.
5. Generally, during the evaluation of the forests tested for powdery mildew, rust, spotting and rotting (decay) diseases, turned out that the most common disease was spotting, which

accounted for 55.1% of all diseases recorded in the studies. The remaining diseases were 2.3% powdery mildew, 0.7% rust and 41.8% rotting diseases.

6. Determined that in the plants studied, various changes were observed in the development cycles of fungi causing various pathologies, depending on the local climate conditions, and it clearly manifests itself in the morphology of the spores and fruit bodies during the observation period of the disease.

LIST OF SCIENTIFIC WORKS PUBLISHED ON THE SUBJECT OF THE DISSERTATION

1. Garayeva A.M., Abbasova T.S., Isgandar E.O. and the head. Species diversity of xylotrophic fungi spreading on some trees in the conditions of Azerbaijan // Scientific works of the Institute of Microbiology of ANAS, 2016, c. 14, № 1, p. 281-285
2. Abdullayeva S.A., Aghayeva T.S., Alibayli N.S. and the head. Evaluation of trees and shrubs used in greening for their resistance to fungal diseases // Scientific works of the Institute of Microbiology of ANAS, 2017, v. 15, p. 302-306
3. Muradov P.Z. Garayeva S.C., Naghiyeva S.E. et al. Characteristics by the species compositions and biological activity of Xylomycobiota of some trees included in the flora of Azerbaijan // Int. J. Adv. Res. Biol. Sci., 2018, 5(8), p.1-4.
4. Alibayli N.S. General characteristics of the xylomycobiota of some forests of Azerbaijan // Scientific works of the Institute of Microbiology of ANAS, 2018, v.16, № 2, p.113-119
5. Alibayli N.S. Density and biological sustainability of the main tree species of some forests in Azerbaijan // Materials of the scientific-practical conference on "Actual problems of modern biology" (05.02.2019, Baku). -Baku, -2019, -p.88-89.
6. Gungor M.S., Abasova T.S., Aliyeva B.N. et al. Species composition and rotten diseases of tree species in

subtropical forests of Azerbaijan. // International Journal of Recent Scientific Research (USA), 2019, v.10, iss.06(A), p. 32722-32725
7. Abasova T.S., Rzayeva A.L., Balakhanova G.V. et al. Species composition of plants used in landscaping cities of Azerbaijan and their mycobiota // Abstracts of XXXI International Scientific and Practical Conference "Trends in the development of modern scientific" (Vancouver, Canada June 22 – 25, 2021) -Vancouver, -2021, p.42-45
8. Alibayli N.S., Abasova T. S., Bakhshaliyeva K.F. Mycobiota of the main forest-forming tree species of Azerbaijan and general characteristics of the pathologies caused by them // Modern science: current problems of theory and practice. Series: Natural and Technical Sciences, 2022. No. 02. - p. 7-10
9. Alibayli N.S. The structure of xylomycobiota of the main forest-forming species of Azerbaijan // Modern science: current problems of theory and practice. Series: Natural and Technical Sciences, -2022. No. 03. - p. 7-10
10. Aliyeva B.N., Alibayli N.S., Abasova, T.S. - The role of xylotrophic macromycetes in the rational use of plant resources // Modern problems of linguistics and teaching methods, -2022, v. 33, No. 3. - p. 582-585
11. Alibayli N.S. General characteristics of fungi spreading in some forests of Azerbaijan due to their species composition and the diseases // Materials of the Republican scientific-practical conference on "New trends and innovations: development prospects of microbiology in Azerbaijan" (01.04.2022, Baku). -Baku, -2022, -p.141-142
12. Muradov P.Z., Alibayli N.S. General characteristics of the xylomycobiota of some forests of Azerbaijan // Materials of the International Scientific Conference dedicated to the 100th anniversary of H. Aliyev on "Actual problems of modern natural and economic sciences". Ganja, 2023, part III, p.107-108.

The defense will be held on "22" october 2024 at _____at the meeting of the Dissertation Council FD 1.07 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at the Institute of Microbiology, the Ministry of Science and Education of the Republic of Azerbaijan.

Address: Az1004, Baku c., A.Abbaszade street, 115.

Dissertation is accessible at the library of the Institute of Microbiology, the Ministry of Science and Education of the Republic of Azerbaijan.

Electronic versions of the dissertation and its abstract are available on the official website of the Institute of Microbiology, the Ministry of Science and Education of the Republic of Azerbaijan (https://azmbi.az/index.php/az/).

Abstract was sent to the required addresses on "13" September 2024.

Signed for printing: 05.08.2024

The format of the paper: A5

Volume: 36726

Number of hard copies: 20