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MYCOBIOTA OF THE WRITTEN HERITAGE OF THE MATENADARAN: FUNGAL BIODIVERSITY AND DISTRIBUTION PATTERNS

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Documentary heritage preserved in libraries and manuscript repositories is susceptible to fungal colonization and biodeterioration, which may threaten the physical integrity and long-term preservation of historical materials. This study presents the results of mycological investigations of the written heritage conducted from 2011 to 2026 at the M. Mashtots Institute of Ancient Manuscripts (Matenadaran), Armenia. A total of 689 documentary objects were examined, including paper and parchment manuscripts, early printed books, and other documentary materials, with the aim of detecting culturable fungi. Fungal isolates were identified primarily on the basis of cultural and morphological characteristics using established mycological identification keys; the nomenclature and taxonomic status of the identified species were verified using the Index Fungorum database. The occurrence of individual species was assessed at the level of individual documentary objects, while fungal diversity was evaluated using the Shannon, Simpson, and Pielou indices. The study revealed considerable fungal diversity: following taxonomic standardization, 95 species of microfungi were recorded, and differences in species composition, frequency of occurrence, and community structure were identified among the examined categories of materials. Several species were repeatedly detected across different categories of documentary materials, whereas others showed more restricted distributions. The highest species diversity was recorded in paper manuscripts, whereas the fungal community of parchment manuscripts was characterized by comparatively lower species diversity and the highest evenness. The findings demonstrate the value of mycological examination as a complement to visual assessment and provide a basis for preventive environmental monitoring, microclimate control, and the development of safer and scientifically grounded approaches to preventing and controlling fungal biodeterioration of written heritage.

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Introduction. Documentary written heritage preserved in libraries, archives, museums, and manuscript repositories represents an irreplaceable source of historical, cultural, scientific, and artistic value. The preservation of these unique collections is threatened by the combined effects of physicochemical and biological

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deterioration. Among biological agents, microscopic fungi are major causes of biodeterioration owing to their high enzymatic activity and ability to colonize a wide range of organic materials, including paper, parchment, leather, textiles, adhesives, and pigments. Their metabolic activity may result in discoloration, staining, weakening of the substrate, degradation of cellulose and proteins, and, in severe cases, irreversible destruction of written heritage [1–3].

The development and composition of fungal communities colonizing written heritage depend on interactions among the physicochemical properties of the substrate, manufacturing technology, environmental conditions, temperature, relative humidity, air circulation, storage conditions, and the physiological characteristics of fungi. Consequently, different documentary materials may provide distinct conditions for fungal colonization and biodeterioration. Investigation of the taxonomic diversity of microscopic fungi colonizing different types of documents is an important prerequisite for assessing biological risks and developing preventive conservation strategies [3, 4].

Although fungal contamination of library and archival collections has been widely studied in Europe, North America, and several Asian countries, most published studies have focused on individual repositories, specific conservation problems, or particular groups of microorganisms. Comparative studies of fungal diversity across different categories of written heritage using a standardized methodological approach remain relatively uncommon. Data on the long-term dynamics of fungal communities are important for understanding and anticipating biodeterioration; however, such long-term monitoring is rarely conducted in archives, which complicates the development of sustainable preventive conservation systems [1, 2, 5].

Armenian documentary heritage preserved at the M. Mashtots Institute of Ancient Manuscripts (Matenadaran) includes manuscripts and early printed books created over many centuries and produced from a wide range of organic materials, including paper, parchment, leather, natural adhesives, pigments, and textiles. Owing to differences in their physicochemical properties and manufacturing technologies, these materials differ substantially in their susceptibility to fungal colonization and biodeterioration [6].

The aim of the present study was to investigate the taxonomic composition, biodiversity, and distribution of microscopic fungi associated with different categories of written heritage at the Matenadaran. The study focused on identifying microscopic fungal species isolated from paper and parchment manuscripts, early printed books, and other documentary materials; comparatively analyzing the structure of their communities on different substrates; and establishing a scientific basis for assessing microbiological risks and implementing preventive conservation measures based on long-term mycological monitoring data.

In the present study, the category “other documentary materials” comprised archival and library materials obtained from other collections and libraries. Thus, the investigated material encompassed not only the Matenadaran collections but also other sources included in the long-term mycological monitoring program. The present work continues a previously established research direction by incorporating the results of fifteen years of continuous observations, comparative analysis of

different categories of documentary materials, and standardization of taxonomic identification in accordance with current nomenclature. The results expand the understanding of the taxonomic diversity and ecology of microscopic fungi associated with Armenian written heritage and provide a basis for assessing biological risks, monitoring microbial contamination, and implementing preventive conservation measures.

Materials and Methods. The present study is based on the results of systematic investigations conducted from 2011 to 2026 as part of the mycological monitoring of written heritage at the M. Mashtots Institute of Ancient Manuscripts (Matenadaran), Yerevan, Armenia. Since October 2024, following the technical upgrading of the institution, mycological investigations have been conducted at the Matenadaran Biochemical Research Laboratory. Before conservation treatment, objects submitted for restoration or exhibition underwent initial mycological assessment. Written heritage objects entering the Matenadaran underwent an initial mycological examination regardless of the purpose of their admission, including accession to the collections, restoration, exhibition, or other forms of use. Following sampling, documents were transferred to a designated area for mechanical surface cleaning to remove dust and subsequent disinfection. Disinfection was performed using vapors of a hydrolate obtained from the essential oil of *Tanacetum argyrophyllum*. The use of this plant-based preparation was based on previously obtained experimental data demonstrating pronounced biocidal activity against fungi responsible for biodeterioration. This enabled the use of hydrolates for preventive treatment of manuscripts and early printed books [7].

During the monitoring period, 689 documentary objects were analyzed. The investigated material comprised 319 paper manuscripts, 25 parchment manuscripts, 290 early printed books, and 55 objects belonging to other categories. The samples represented different chronological periods and varied in manufacturing technology, substrate composition, and degree of biodeterioration.

***Sampling and Isolation of Fungal Isolates*.** Mycological sampling directly from the surfaces of documentary materials was performed using sterile lancets. Sampling was routinely carried out for each investigated object regardless of the presence or absence of visible signs of fungal contamination. Each individual object served as the sampling unit. All fungal species detected on a given object were recorded under the corresponding object number and counted only once. In materials showing visible signs of biodeterioration, including pigmentation, discoloration, or structural changes in the substrate, samples were collected from affected areas. Sampling was also performed in the absence of visible biodeterioration, because the absence of macroscopic manifestations does not exclude hidden contamination by microfungi. The collected material was inoculated directly onto Petri dishes containing Czapek agar and Wort agar. Cultures were incubated at 26 ± 1°C. Preliminary assessment of mycelial growth was performed on day 5, while the final evaluation of cultural and morphological characteristics was conducted on day 10 of cultivation. Developing microfungal colonies were isolated and, when necessary, subcultured to obtain pure cultures for subsequent species identification.

***Identification of Fungal Isolates*.** Taxonomic identification of the isolated cultures was performed on the basis of cultural and morphological characteristics

using light microscopy with a Euromex iScope microscope (magnification ×10÷×100). Isolates that could not be reliably identified to species level were classified to the genus level and excluded from subsequent species-diversity calculations. Identification was performed using specialized mycological identification keys, including the works of Bilai and Koval [8], Pidoplichko [9], Litvinov [10], and Barnett and Hunter [11].

***Taxonomic and Statistical Analysis*.** Initial species identification was performed using available mycological identification keys, after which the names were brought into conformity with current nomenclatural status using the Index Fungorum database. Synonymous names referring to the same species were consolidated for subsequent data analysis. Species composition was analyzed separately for paper and parchment manuscripts, early printed books, and other documentary materials.

Each individual documentary object served as the sampling unit. Accordingly, repeated isolation of the same microfungal species from different areas or pages of a single document was recorded as one occurrence and counted only once in the overall statistics. The frequency of occurrence of each fungal species was calculated according to Mirchink [12] as the percentage of documentary objects in which the respective species was detected:

$$F = (n_i / N) \times 100,$$

where n_i is the number of documentary objects, in which species i was detected, and N is the total number of documentary objects examined in the corresponding category.

Species diversity was assessed using the Shannon diversity index (H') [13]. The Shannon index H' reflects fungal community diversity by taking into account both the number of species detected and the evenness of their occurrence:

$$H' = -\Sigma\, p_i \ln (p_i),$$

where p_i is the relative frequency of species i, calculated as the ratio of the number of documentary objects, in which the species was detected to the total number of occurrences of all fungal species in the corresponding category.

Thus, the diversity indices were calculated on the basis of species occurrence among the investigated documentary objects rather than the quantitative abundance of individual colonies or isolates.

The Simpson diversity index was calculated as $1-D$ [14], where:

$$D = \Sigma\, p_i^2.$$

Pielou's evenness index (J) was calculated as $J = H' / \ln (S)$ [15], where S is the total number of species recorded at species level in the corresponding category of documentary materials.

Isolates with uncertain taxonomic status (identified only to the genus level), as well as Mycelia sterilia forms, were excluded from subsequent calculations of species-diversity indices. The Shannon, Simpson, and Pielou indices were calculated separately for each material category to compare the diversity and evenness of fungal communities across different substrates.

Results and Discussion. Long-term mycological monitoring revealed considerable fungal diversity associated with the investigated written heritage. The species composition and distribution of microfungi across the four categories of documentary materials are presented in Tab. 1. As shown by the data, a total of 95 fungal species were identified, belonging to 3 phyla, 4 subphyla, 9 classes, 7 subclasses, 17 orders, 26 families, and 37 genera.

Table 1

Species composition and distribution of microfungi detected in different categories of documentary materials

№	Fungal species	Manuscripts		Early printed books	Other documentary materials
		paper	parchment		
1.	*Acremonium charticola* (Lindau) W. Gams	–	–	+	–
2.	*Alternaria alternata* (Fr.) Keissl.	+	+	+	+
3.	*Alternaria tenuior*	–	–	+	–
4.	*Alternaria terricola* J.W. Ellis & G. Martin	+	–	–	–
5.	*Aphanoascus keratinophilus* (Vanbreuseghem) Apinis	+	–	–	–
6.	Arthrobotrys arthrobotryoides Drechsler	+	–	–	–
7.	*Arthrobotrys oligospora* Fresen.	+	+	–	–
8.	*Aspergillus anomalus* Kwon–Chung & Fennell	+	–	–	–
9.	*Aspergillus auratus* (Georg) Corda	+	+	–	–
10.	*Aspergillus avenaceus* G. Smith	–	–	+	–
11.	*Aspergillus flavus* Link	+	+	+	+
12.	*Aspergillus fumigatus* Fresen.	+	+	+	–
13.	*Aspergillus glaucus* (L.) Link	+	–	+	–
14.	*Aspergillus niger* Tiegh.	+	+	+	+
15.	*Aspergillus ochraceus* G. Wilh.	+	–	+	+
16.	*Aspergillus versicolor* (Vuill.) Tirab.	+	–	+	+
17.	*Aureobasidium pullulans* (de Bary) G. Arnaud	–	–	+	–
18.	*Beauveria bassiana* (Bals.–Criv.) Vuill.	–	–	+	–
19.	*Botryoderma lateritium* (Berk.)	+	–	–	–
20.	*Chaetomium olivaceum* Cooke & Ellis	+	–	–	–
21.	*Chaetomium venezuelense* Cif.	+	–	–	–
22.	*Chloridium apiculatum* (J. Lindau) S. Hughes	+	–	–	–
23.	*Chromelosporium fulvum* (Link) D. Hawksw.	–	–	+	–
24.	*Cladosporium brevicompactum* G.A. de Vries	+	–	+	–
25.	*Cladosporium elegantulum* Cooke & Massee	+	–	+	–
26.	*Cladosporium herbarum* (Pers.) Link	+	+	+	+
27.	*Cladosporium lignicola* Corda	+	–	–	–
28.	*Cladosporium linicola* G.A. de Vries	+	–	+	+
29.	*Cladosporium transchelii* B. Sutton	+	–	–	+
30.	*Dicoccum asperum* (Corda) S. Hughes	+	–	+	–
31.	*Epicoccum nigrum* Link	+	–	–	–
32.	*Fulvia fulva* (Cooke) Cif.	–	–	+	–
33.	*Fusarium lateritium* Nees	+	–	–	–
34.	*Fusarium oxysporum f. sp. solani* (Mart.) Appel & Wollenw.	+	–	–	–
35.	*Fusarium verticillioides* (Sacc.) Nirenberg	–	–	+	–
36.	*Geotrichum candidum* Link	+	–	–	–
37.	*Hormiscium punctiforme* Harz	+	–	–	–
38.	*Oidiodendron nigrum* Robak	+	–	–	–

39.	*Papulaspora irregularis* Hotson	+	–	–	–
40.	*Penicillium albocinerascens* Frisvad	+	–	–	–
41.	*Penicillium atrovenetum* G. Smith	–	–	–	+
42.	*Penicillium aurantiogriseum* Dierckx	+	+	+	+
43.	*Penicillium brevicompactum* Dierckx	+	–	+	–
44.	*Penicillium camemberti* Thom	+	+	+	–
45.	*Penicillium canescens* Sopp	+	–	–	+
46.	*Penicillium casei* Pitt, A.D. Hocking & Frisvad	+	+	–	–
47.	*Penicillium chermesinum* Biourge	+	–	+	–
48.	*Penicillium chrysogenum* Thom	+	–	–	–
49.	*Penicillium citrinum* Thom	+	–	–	+
50.	*Penicillium cluniae* Pitt	+	–	–	–
51.	*Penicillium commune* Thom	–	–	+	–
52.	*Penicillium decumbens* Thom	+	–	–	–
53.	*Penicillium expansum* Link	+	+	+	+
54.	*Penicillium glabrum* (Wehmer) Westling	–	–	–	+
55.	*Penicillium godlewskii* Zaleski	+	–	–	–
56.	*Penicillium gorlenkoanum* Biourge	–	–	–	+
57.	*Penicillium granulatum* Bainier	–	–	+	–
58.	*Penicillium griseolum* Pitt	+	–	–	–
59.	*Penicillium griseopurpureum* Dierckx	+	–	–	+
60.	*Penicillium hordei* Stolk	+	–	–	–
61.	*Penicillium italicum* Wehmer	–	–	+	–
62.	*Penicillium lanosoviride* Biourge	+	+	–	–
63.	*Penicillium lanosum* Westling	+	+	+	+
64.	*Penicillium luteoaurantium* Biourge	+	–	–	–
65.	*Penicillium madriti* Biourge	+	+	–	+
66.	*Penicillium puberulum* Bainier	+	–	–	–
67.	*Penicillium purpurascens* G. Smith	–	–	–	+
68.	*Penicillium raistrickii* G. Smith	+	–	–	–
69.	*Penicillium resticulosum* Birkinshaw & G. Smith	+	–	–	–
70.	*Penicillium solitum* Westling	+	–	+	–
71.	*Penicillium soppii* K.M. Zaleski	+	–	–	–
72.	*Penicillium stoloniferum* Thom	+	–	–	–
73.	*Penicillium velutinum* J.F.H. Beyma	+	+	–	–
74.	*Penicillium viridicatum* Westling	+	–	–	+
75.	*Rhizoctonia solani* J.G. Kühn	+	+	–	–
76.	*Rhizopus stolonifer* (Ehrenb.) Vuill.	+	+	+	+
77.	*Sarocladium strictum* (W. Gams) Summerbell & Schroers	+	–	–	–
78.	*Scolecobasidium constrictum* Abbott	+	–	–	–
79.	*Scolecobasidium verruculosum* Barron & Busch	+	–	–	–
80.	*Scopulariopsis microascus* (H.C.J. Schel.) H.C.J. Schöl–Schwarz	+	–	–	–
81.	*Scytalidium lignicola* Pesante	+	–	–	–
82.	*Sepedonium albogriseum* Sacc.	+	–	–	–
83.	*Sporotrichum olivaceum* (Berk. & Broome) G. Smith	–	–	+	–
84.	*Stachybotrys chartarum* (Ehrenb.) S. Hughes	+	–	–	–
85.	*Stemphylium botryosum* Wallr.	+	–	+	–
86.	*Stemphylium verruculosum* E.G. Simmons	–	–	+	–
87.	*Talaromyces diversus* (Raper & Fennell) C.R. Benj.	–	–	+	–

88.	*Talaromyces purpureogenus* (Stoll) Samson, N. Yilmaz, Frisvad & Seifert	+	–	+	–
89.	*Thamnidium elegans* Link	+	–	–	–
90.	*Thermomyces lanuginosus* Tsikl.	+	–	–	–
91.	*Trichoderma viride* Pers.	+	–	+	–
92.	*Trichosporiella hyalina* (Berk. & Broome) G. Arnaud	+	–	+	–
93.	*Trichothecium laxicephalum* J. Lindau	+	–	–	–
94.	*Trichothecium roseum* Link	+	–	–	–
95.	*Verticillium glaucum* Bonord.	–	–	–	+

Note: + indicates that the corresponding fungal species was detected in the respective category of documentary materials.

Comparative analysis of species composition showed that some fungal species occurred in several categories of documentary materials, whereas a substantial proportion of species was detected in only one category. In particular, *Aspergillus niger*, *Aspergillus flavus*, *Penicillium aurantiogriseum*, *Penicillium expansum*, *Penicillium lanosum*, *Alternaria alternata*, *Cladosporium herbarum*, and *Rhizopus stolonifer* were detected in all four categories examined. Their repeated occurrence indicates that these species constitute a common component of the mycobiota associated with the investigated written heritage. At the same time, a considerable number of species occurred only within a single material category, highlighting differences in the species composition of fungal communities associated with different types of documentary materials.

Fungal Diversity of Paper Manuscripts. Over the entire monitoring period, 319 paper manuscripts were examined, from which 76 fungal species were identified. *Aspergillus niger* was detected most frequently, occurring in 51 manuscripts (15.99%). High occurrence frequencies were also recorded for *Penicillium aurantiogriseum* – 48 objects (15.05%), *P. lanosum* – 47 (14.73%), *P. expansum* – 27 (8.46%), *Rhizopus stolonifer* – 21 (6.58%), and *Aspergillus flavus* – 17 (5.33%). The remaining 70 species occurred considerably less frequently; 10 species were detected in only one manuscript (0.31%).

Thus, the mycobiota of paper manuscripts was characterized by a combination of several widely distributed species and a substantial number of rarely detected taxa.

Fungal Diversity of Parchment Manuscripts. Mycological analysis was performed on 25 parchment manuscripts. Fungal growth was detected on 14 of them, whereas no fungal growth was detected on the remaining manuscripts. Species identification resulted in the detection of 17 microfungal species. The highest occurrence frequency was recorded for *Penicillium aurantiogriseum*, detected in 8 manuscripts (32%). This was followed by *P. lanosum* – 5 objects (20%), and *Alternaria alternata* and *Aspergillus fumigatus* – 3 objects each (12%). *Aspergillus flavus* and *A. niger* were detected in 2 objects each (8%). *Penicillium camemberti*, *P. casei*, *P. expansum*, *P. lanosoviride*, *P. madriti, and P. velutinum* were also detected in 2 objects each (8%), whereas *Rhizopus stolonifer* was detected in 1 object (4%). The remaining four species were detected in 1 object each (4%). Thus, the mycobiota of parchment manuscripts was characterized by the predominance of several frequently occurring species together with a substantial proportion of taxa detected at low frequency. The parchment manuscript No. 11203, fungal colonies

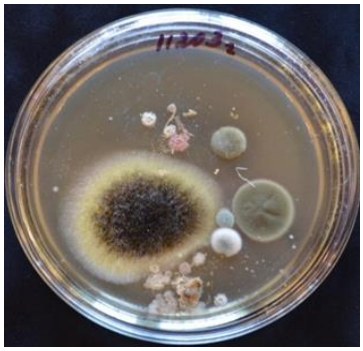
isolated from its surface, and the microscopic appearance of *Aspergillus niger* are presented in Figure.



a



b



c



d

a, b – Manuscript No 11203; c – *Aspergillus niger* Tiegh. detected on the manuscript (Petri dish culture); d – photomicrograph of *A. niger* Tiegh. (×40) isolated from the manuscript.

***Fungal Diversity of Early Printed Books*.** During the study, 290 early printed books were subjected to mycological analysis, resulting in the identification of 38 species of microfungi. The highest occurrence frequency was recorded for *Penicillium aurantiogriseum* – 34 objects (11.72%). This was followed, in descending order, by the representatives of the genus *Aspergillus: A. niger and A. flavus* – 23 objects each (7.93%). The group of associated biodeteriorative fungi included *Rhizopus stolonifer* and *P. expansum* – 17 objects each (5.86%), as well as *P. lanosum* – 16 objects (5.52%). *Alternaria alternata* was isolated from 12 books (4.14%), whereas *Cladosporium herbarum* was isolated from 7 books (2.41%). The remaining mycobiota was characterized by low occurrence frequencies; 10 species were detected only once (0.34% for each species).

Thus, the fungal community of early printed books was characterized by the predominance of several relatively frequent species together with a substantial proportion of rarely or singly detected species.

Fungal Diversity of Other Documentary Materials. Mycological analysis was performed on 55 documentary objects not belonging to the Matenadaran book collections. Following taxonomic standardization, 22 species of microfungi were identified in this group. The highest occurrence frequency was recorded for *A. niger* and *P. aurantiogriseum* – 11 objects each (20% for each species). This was followed by *P. lanosum*, detected in 10 objects (18.18%). The most frequently occurring associated species included *Alternaria alternata*, *Aspergillus flavus*, and *Cladosporium transchelii*, each detected in 4 objects (7.27%), while *Aspergillus ochraceus* was detected in 3 objects (5.45%). The remaining species occurred at lower frequencies: *C. herbarum*, *C. linicola*, *P. atrovenetum*, *P. canescens*, *P. citrinum*, *P. expansum*, *P. glabrum*, *P. gorlenkoanum*, *P. griseopurpureum*, *P. madriti*, *P. purpurascens*, *P. viridicatum*, and *Rhizopus stolonifer* were detected in 1–3 objects (1.82–5.45%).

Comparison of species composition demonstrated both substantial similarity and distinct differences between the mycobiota of these materials and that of the manuscripts and early printed books preserved in the Matenadaran. Of the 22 species identified in this group, 13 were also recorded in at least one of the main categories of Matenadaran documentary heritage. The shared species were *A. alternata*, *Aspergillus flavus*, *A. niger*, *A. ochraceus*, *A. versicolor*, *Cladosporium herbarum*, *C. linicola*, *Penicillium aurantiogriseum*, *P. expansum*, *P. lanosum*, *P. madriti*, *P. viridicatum*, and *Rhizopus stolonifer*. This similarity indicates the presence of a common complex of microfungi capable of colonizing different types of documentary materials irrespective of their origin and previous storage conditions.

At the same time, 9 species – *C. transchelii*, *P. atrovenetum*, *P. canescens*, *P. citrinum*, *P. glabrum*, *P. gorlenkoanum*, *P. griseopurpureum*, *P. purpurascens*, *and Verticillium glaucum* – were recorded only among the other documentary materials in the combined dataset. Thus, the presence of a specific component of the mycobiota distinguishes this group from the manuscripts and early printed books of the Matenadaran. However, this difference should not be interpreted as direct evidence of the external origin of the detected species, because the mycobiota of documentary objects is determined by a combination of factors, including the initial condition of the material, the nature of contamination, previous storage conditions, microclimate, and intensity of use.

Thus, the mycobiota of the other documentary materials showed substantial similarity to that of the principal collection groups of the Matenadaran, while also containing a number of species recorded only in this group. This combination of shared and specific taxa indicates that the origin of documentary objects may influence the formation of their mycobiota; however, the observed differences likely reflect the combined effects of storage conditions and the individual preservation history of each object.

To elucidate patterns of biodeterioration in relation to the nature of the material substrate, a comparative analysis of fungal communities colonizing the different categories of investigated documents was performed. Differences were assessed using the number of examined objects (N), species diversity (S), and the Shannon (H'), Simpson ($1-D$), and Pielou (J) indices. The resulting values are presented in Tab. 2.

The highest species diversity and the highest Shannon and Simpson index values were recorded for paper manuscripts. Parchment manuscripts exhibited comparatively low species diversity but the highest Pielou index value, indicating the most even distribution of the detected species. Other documentary materials showed relatively high Shannon, Simpson, and Pielou index values at a species diversity of $S = 22$. Early printed books exhibited intermediate species diversity and a lower evenness value than parchment manuscripts and other documentary materials.

Table 2

Comparative analysis of microfungal across different categories of documentary materials

Documentary material	Species diversity, S	Number of examined objects, N	Shannon index, H'	Simpson index, $1-D$	Pielou index, J
Paper manuscripts	76	319	3.548	0.947	0.819
Early printed books	38	290	3.013	0.926	0.828
Other documentary materials	22	55	2.825	0.923	0.914
Parchment manuscripts	17	25	2.663	0.915	0.940

Thus, the calculated indices reflect differences in species diversity, community structure, and evenness among the investigated categories of documentary materials.

Influence of Substrate, Preservation History, and Sampling Limitations. The results obtained for parchment manuscripts indicate the need for further investigation and cautious interpretation, taking into account the limited sample size. During the study period, 25 parchment manuscripts were subjected to mycological analysis. The limited sample size was determined by the objective schedule of object submission to the laboratory during the study period rather than by intentional sample selection. Compared with paper documents, parchment manuscripts are less frequently submitted for restoration and related examination procedures, which limited the number of available objects for analysis.

It should be noted that the comparatively low fungal diversity observed in parchment does not indicate inherently high resistance to fungal deterioration. As a collagen-containing material, parchment may undergo fungal biodeterioration under certain environmental conditions. The current microbiological status of such materials may reflect the combined effects of substrate properties, microclimatic parameters, storage history, and previous conservation treatments.

Another factor that should be considered is the preservation history of the Matenadaran collections. During the Soviet period, part of the written heritage underwent disinfection, including treatments involving thymol and formaldehyde. Such interventions may have influenced the culturable fungal communities recovered from some objects in the present study. However, because detailed information on the restoration and disinfection history of individual documents is unavailable, the effects of previous disinfection should be regarded only as a potential contributing factor rather than as a demonstrated cause of lower fungal detectability on particular substrates.

Thus, differences among the categories of documentary materials should be interpreted in the context of both biological and methodological factors, including sample size, substrate properties, environmental history, and previous conservation interventions.

***Significance for Preventive Conservation and Microbiological Monitoring*.** From the perspective of preventive conservation, the findings emphasize the importance of regular mycological monitoring of documentary materials, including their examination upon submission for microbiological assessment, irrespective of the purpose of their subsequent use or conservation treatment. Such analysis provides information that cannot always be obtained through visual examination alone. The absence of visually detectable signs of mycelial growth is not a reliable criterion for excluding fungal contamination of the substrate and does not rule out the presence of viable fungal propagules.

The repeated detection of several fungal species across different categories of documentary materials further highlights the importance of preventive environmental control. Appropriate control of humidity, temperature, ventilation, and storage conditions is essential for reducing factors favorable to fungal development. Therefore, mycological monitoring can complement environmental monitoring and visual assessment within an integrated preventive conservation strategy.

The findings provide a practical basis for developing safer approaches to the microbiological control of written heritage. In this context, the present study complements previously published laboratory research demonstrating pronounced antifungal activity of Tanacetum argyrophyllum. These findings support the potential of plant-based antifungal agents in the preventive conservation of documentary materials, provided that their efficacy, substrate compatibility, and long-term effects on material preservation are adequately evaluated.

Conclusion. The present study provides a long-term assessment of culturable fungal communities associated with written heritage investigated and preserved at the Matenadaran. A comprehensive analysis of paper and parchment manuscripts, early printed books, and other documentary materials revealed considerable species diversity and differences in species composition, frequency of occurrence, and fungal community structure among the investigated material categories.

Paper manuscripts exhibited the highest species diversity (76 species) as well as the highest Shannon and Simpson index values. In contrast, the comparatively low species diversity recorded for parchment manuscripts (17 species) was accompanied by the highest Pielou evenness value, indicating a more even distribution of the detected species. These characteristics should be interpreted in light of the sample size and preservation history of the investigated objects and should not be directly attributed to inherently high resistance of parchment to fungal biodeterioration.

Comparison of species composition demonstrated a substantial number of species shared among manuscripts, early printed books, and other documentary materials, indicating a common component of the mycobiota associated with written heritage. At the same time, the detection of several species exclusively among the other documentary materials, which do not belong to the principal book collections of the Matenadaran, indicates differences in fungal community structure. These differences may be associated with substrate properties, previous storage conditions,

microclimate, patterns of use, and the individual preservation history of particular objects. The origin of a document alone cannot be regarded as the sole factor determining the composition of its mycobiota.

The findings emphasize the importance of mycological examination as a complement to visual assessment of the condition of documentary objects and provide a basis for continued preventive mycological monitoring, microclimate control, and the development of scientifically grounded and safe approaches to preventing and controlling fungal biodeterioration of written heritage.

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Ա. Ե. ՊԱՐՈՆԻԿՅԱՆ

ՄԱՏԵՆԱԴԱՐԱՆԻ ԳՐԱՎՈՐ ԺԱՌԱՆԳՈՒԹՅԱՆ ՄԻԿՈԲԻՈՏԱՆ. ՍՆԿԵՐԻ ԿԵՆՍԱԲԱԶՄԱԶԱՆՈՒԹՅՈՒՆԸ ԵՎ ԴՐԱՆՑ ՏԱՐԱԾՄԱՆ ԱՌԱՆՁՆԱՀԱՏԿՈՒԹՅՈՒՆՆԵՐԸ

Գրադարաններում և ձեռագրապահոցներում պահպանվող գրավոր ժառանգությունը ենթակա է սնկային գաղութացման և կենսավնասման, որոնք կարող են վտանգել պատմական նյութերի ֆիզիկական ամբողջականությունը և երկարաժամկետ պահպանությունը: Սույն ուսումնասիրությունը ներկայացնում է Հայաստանի Մեսրոպ Մաշտոցի անվան հին ձեռագրերի ինստիտուտ (Մատենադարան) 2011–2026 թ.-րի ընթացքում իրականացված միկոլոգիական հետազոտության արդյունքները: Ընդհանուր առմամբ ուսումնասիրվել է 689 փաստաթղթային օբյեկտ՝ ներառյալ թղթե և մագաղաթյա ձեռագրեր, հնատիպ գրքեր և այլ փաստաթղթային նյութեր՝ կուլտիվացվող սնկերի հայտնաբերման նպատակով: Սնկային մեկուսացված կուլտուրաների նույնականացումն իրականացվել է հիմնականում կուլտուրալ և մորֆոլոգիական հատկանիշների հիման վրա՝ կիրառելով ընդունված սնկաբանական որոշիչներ, իսկ հայտնաբերված տեսակների անվանումներն ու տաքսոնոմիական դիրքը ստուգվել են Index Fungorum տվյալների շտեմարանի միջոցով: Առանձին տեսակների հանդիպումը գնահատվել է փաստաթղթային օբյեկտների մակարդակով, իսկ սնկային բազմազանությունը՝ Շենոնի, Սիմփսոնի և Պիելուի ինդեքսների միջոցով: Հետազոտության արդյունքում ստանդարտացված տաքսոնոմիական կազմի շրջանակում արձանագրվել է 95 տեսակ և բացահայտվել է սնկային զգալի բազմազանություն, ինչպես նաև ուսումնասիրված նյութերի խմբերի միջև տեսակային կազմի, հաճախականության և համայնքային կառուցվածքի տարբերություններ: Մի շարք տեսակներ բազմիցս հայտնաբերվել են փաստաթղթային նյութերի տարբեր կատեգորիաներում, մինչդեռ մյուսներն ունեցել են ավելի սահմանափակ տարածում: Թղթե ձեռագրերում արձանագրվել է սնկային բազմազանության ամենաբարձր ցուցանիշը, մինչդեռ մագաղաթյա ձեռագրերի սնկային համայնքը բնութագրվել է համեմատաբար ցածր տեսակային բազմազանությամբ և ավելի բարձր հավասարաչափությամբ: Ստացված արդյունքները ցույց են տալիս միկոլոգիական հետազոտության կարևորությունը՝ որպես տեսողական զննման լրացուցիչ գործիք, և հիմք են ստեղծում կանխարգելիչ միջավայրային մոնիթորինգի ու գրավոր ժառանգության սնկային կենսավնասման վերահսկման ավելի անվտանգ և գիտականորեն հիմնավորված մոտեցումների զարգացման համար:

А. Е. ПАРОНИКЯН

МИКОБИОТА ПИСЬМЕННОГО НАСЛЕДИЯ МАТЕНАДАРАНА: БИОРАЗНООБРАЗИЕ ГРИБОВ И ОСОБЕННОСТИ ИХ РАСПРОСТРАНЕНИЯ

Письменное наследие, хранящееся в библиотеках и хранилищах рукописей, подвержено колонизации грибами и биоповреждению, что может

угрожать физической целостности исторических материалов и их долговременному сохранению. В настоящей работе представлены результаты микологического исследования письменного наследия, проведенного в 2011–2026 гг. в Институте древних рукописей имени Месропа Маштоца (Матенадаран), Армения. Всего было исследовано 689 документальных объектов, включая рукописи на бумаге и пергаменте, старопечатные книги и другие документальные материалы, с целью выявления культивируемых грибов. Идентификацию выделенных грибных культур проводили преимущественно на основании культуральных и морфологических признаков с использованием общепринятых микологических определителей. Номенклатура и таксономическое положение выявленных видов проверялись по базе данных Index Fungorum. Частоту встречаемости отдельных видов оценивали на уровне отдельных документальных объектов, а грибное разнообразие – с использованием индексов Шеннона, Симпсона и Пиелу. Исследование выявило значительное грибное разнообразие: после таксономической стандартизации было зарегистрировано 95 видов микромицетов, а также установлены различия в видовом составе, частоте встречаемости и структуре грибных сообществ между исследованными категориями материалов. Ряд видов неоднократно обнаруживался в различных категориях документальных материалов, тогда как другие имели более ограниченное распространение. Наиболее высокое видовое разнообразие отмечено для бумажных рукописей, тогда как грибное сообщество пергаментных рукописей характеризовалось относительно меньшим видовым разнообразием и наиболее высокой равномерностью распределения видов. Полученные результаты демонстрируют значение микологического исследования как дополнения к визуальному обследованию и создают основу для профилактического экологического мониторинга, контроля микроклимата и разработки более безопасных и научно обоснованных подходов к предупреждению и контролю грибного биоповреждения письменного наследия.