

Ecological and Taxonomic Characteristics of Microscopic Fungi Distributed in Alluvial and Brown Soils of Georgia

ABSTRACT

The study of soil microbial biodiversity is one of the priority areas of modern ecological science. Although microscopic fungi ~~are among~~ ~~represent one~~ of the most diverse and ecologically active components of soils, information on their distribution, taxonomic composition, and ecological characteristics in Georgia remains scarce. The present research provides a comparative analysis of the mycoflora in alluvial and brown soils from various pedological regions of Georgia. The study was conducted on alluvial and brown soils from Western, Eastern, and Southern Georgia. Alluvial soil samples were collected from three distinct microrelief zones within each region, within a ~~radius of~~ 50 cm ~~radius~~, at depths of 10–20 cm, under maximum sterile conditions. Pure cultures of microscopic fungi were obtained using standard methods and stored in test tubes on slanted agar medium at 4 °C ~~in a refrigerator~~. Taxonomic identification (to the genus level) was based on macro- and micromorphological characteristics, including the structure and arrangement of hyphae, conidia, and spores. The dominant genera identified in alluvial soils are *Penicillium* and *Aspergillus*. The distribution of other genera varies greatly among regions: in Eastern Georgia ~~predominate~~ xerotolerant fungi ~~predominate~~; in Western Georgia hygrophilous and humus-loving taxa are prevalent; while in Southern Georgia, under mixed ecotonal conditions, representatives of both groups are present.

The mycoflora of brown soils in Eastern and Southern Georgia was found to be relatively similar, whereas in Western Georgia it differed markedly, likely due to ~~the influence of~~ local climate and ~~the soil physicochemical properties~~ ~~of the soil~~. The results confirm that the taxonomic structure of soil mycoflora clearly reflects the combined effects of geographical location and abiotic factors. This underlines the bioindicator potential of soil fungal communities and their importance for the study of fundamental ecological processes.

Keywords: *alluvial and brown soils, soil mycoflora, taxonomic diversity, soil bioindication, ecotonal zone*

1. INTRODUCTION

One of the priority directions in modern ecological research is the study of soil biodiversity, as it determines ecosystem stability and functional resilience. Among the most diverse ~~and~~ ecologically important groups of soil microbiota are microscopic fungi, which occur in almost all soil types (Classen et al., 2003). Their biological activity significantly contributes to biogeochemical cycles, humus formation, the decomposition of organic residues, and the accumulation of nutrients in the soil. It is known that 60–90% of cellulose-decomposing microorganisms are represented by soil micromycetes (Blume, 2004).

Despite their important ecological role, there is still a lack of data on the geographical distribution patterns of microscopic fungi. This deficit may be due to their highly specialized and heterogeneous nature, which complicates systematization and accurate modeling of their ecological niches.

The distribution of fungi is strongly influenced by the physicochemical properties of the soil, climatic conditions, and habitat type. Different geographical zones are characterized by distinct soils, vegetation, temperature, humidity, and pH levels, all of which largely determine the composition and functional structure of mycoflora (Derry et al., 2004). Consequently, ecological studies of microscopic fungi must be conducted on a regional basis to identify the interrelationship between geographical zonation, soil type, and climatic factors.

The aim of the present research is to provide a comparative analysis of the taxonomic diversity and distribution characteristics of microscopic fungi in alluvial and brown soils from Western, Eastern, and Southern Georgia. The study focuses on identifying the general distribution regularities of the microscopic fungi, thereby improving the ecological structure analysis of Georgia's soil mycobiota.

2. MATERIAL AND METHODS

The study was conducted on alluvial and brown soils from Western, Eastern, and Southern Georgia. Alluvial soil samples were collected from three distinct microrelief zones within each region, within a 50-cm radius of 50 cm, at depths of 10–20 cm, under maximum sterile conditions (Fomin & Fomin, 2001). In particular, the alluvial soil sampling sites were the banks of the Gubistskali River (Western Georgia), the bank of the Mtkvari River (Eastern Georgia), and the bank of the Fotskhovi River (Southern Georgia).

Brown soil samples were collected from the following locations: Bakhmaro (Western Georgia), Tskhvarichamia (Eastern Georgia), and Manglisi (Southern Georgia).

Isolation of microscopic fungi from the soil samples was performed using the classical soil dilution plate method (Waksman, 1922). The primary sowings were incubated in Petri dishes at 28–30 °C for 10 days, using a universal agar medium of the following composition: wort – 0.5 L; tap water – 0.5 L; agar-agar – 20 g; pH 5.5–6.0. Sterilization was carried out at 0.7 atm for 40 minutes.

Pure cultures of microscopic fungi were obtained using standard methods (Shavadze et al., 2024) and stored in test tubes on slanted agar medium at 4 °C in a refrigerator.

Taxonomic identification (to the genus level) was based on macro- and micromorphological characteristics, including the structure and arrangement of hyphae, conidia, and spores. Relevant diagnostic literature and atlases were used for identification (Chaverri et al., 2003; Samuels, 2003; Domsch et al., 2007; Pitt & Hocking, 2009; Dugan, 2006; Malloch, 1981).

3. RESULTS AND DISCUSSION

Three pedological regions can be distinguished in Georgia, considering various geographical factors: Western, Eastern, and Southern Georgia. Only two soil types are common to all three: alluvial and brown. The purpose of this research was to conduct a comparative analysis of the composition of mycoflora of the same soil types (alluvial and brown) across different geographical regions of Georgia, and to determine the patterns of distribution of a particular genus of microscopic fungi.

It is known that alluvial soils are result the result of accumulating processes in a river. These soils occur in all landscape zones, with varying thicknesses and particle-size compositions (<https://soilsmatter.wordpress.com/2020/02/15/what-are-alluvial-soils/>).

The mycoflora of alluvial soils from the three pedological regions of Georgia proved to be differed (Fig. 1). The highest fungal diversity (14 genera) was recorded in Western Georgia; Southern Georgia alluvial

soils yielded 12 genera, and Eastern Georgia soils yielded only 7. This quantitative difference correlates well with the ecological characteristics of each region.

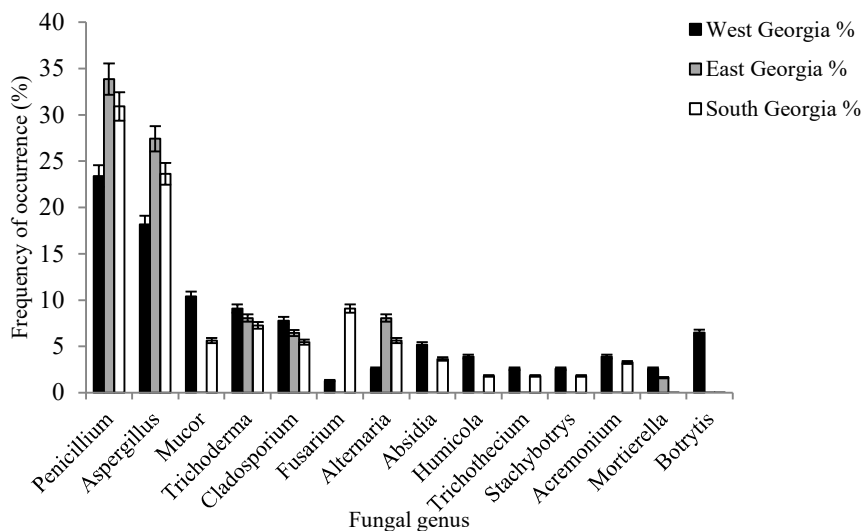


Fig. 1. Frequency of occurrence (%) of genera of microscopic fungi in alluvial soils across different pedological regions of Georgia.

The comparative analysis of alluvial soil mycoflora demonstrates that ecological conditions have a significant impact on the formation of taxonomic diversity and dominant genera composition of microscopic fungi (Fig. 1). Common to all regions, dominant genera were *Penicillium* and *Aspergillus*, while the distribution of other taxa is closely linked to geo-ecological characteristics.

The humid climate of Western Georgia, combined with a relatively stable temperature regime and humus-rich soils, favors the proliferation of both ascomycetes (Phylum: *Ascomycota*, including *Aspergillus*, *Penicillium*, *Fusarium*, *Cladosporium*, *Trichoderma*) and representatives of the phyla *Mucoromycota* (*Mucor*, *Absidia*) and *Mortierellomycota* (*Mortierella*). Additionally, hyphomycetous morphotypes belonging to *Ascomycota* (e.g., *Botrytis*, *Trichothecium*, *Stachybotrys*) are noteworthy.

The xerophilic conditions of Eastern Georgia—dry climate, high temperature amplitude, and relatively low soil moisture—limit the diversity of microscopic fungi. The mycoflora here is represented by a smaller number of genera, although dominant xerotolerant genera such as *Aspergillus* and *Penicillium* remain prevalent. Their widespread occurrence is likely explained by due to intensive sporogenesis and efficient airborne dispersal mechanisms. The presence of *Fusarium* and *Alternaria* suggests an influence of abundant plant residues. Notably, *Fusarium* is particularly common in drought-affected soils and is often associated with stressed, anthropogenically influenced zones (Summerell et al., 2010).

The relatively high diversity of alluvial soil mycoflora in Southern Georgia may be explained by its mixed-type climate and microrelief variation. Alluvial soils in this zone retain the organic richness characteristic of Western Georgia as well as the water-deficient regime typical of Eastern Georgia, creating a natural ecotonal zone. Both hygrophilous and xerotolerant fungal genera coexist here, further underscoring the influence of microclimate and substrate type on the mycoflora structure.

Modern classification of soil mycoflora is based on phylogenetic data. Consequently, most genera of microscopic fungi isolated from alluvial soils belong to *Ascomycota*, which dominates in soils due to its

metabolic diversity and ecological plasticity (Hawksworth & Lücking, 2017). In the past, the term *Deuteromycota* was often used, but in current classification this group has been abolished, and its formerly assigned genera—such as *Cladosporium*, *Alternaria*, and *Acremonium*—are now included in *Ascomycota* (Kirk et al., 2011). As for representatives of the former *Zygomycota* (e.g., *Mucor*, *Absidia*, *Mortierella*), they are now assigned to the redefined phylum *Mucoromycota*, which occurs in small quantities but is widespread, especially in moist and humus-rich soils (Spatafora et al., 2016). This updated classification provides a more accurate understanding of ecological niches and the functional structure of mycoflora.

Brown soils cover 18% of ~~the territory of Georgia's territory~~. They develop under various forest covers, ~~are characterized by have~~ an undifferentiated profile, and exhibit a ~~more-or-less~~-distinct dark-grey coloration.

Among the studied brown soils, the highest diversity of mycoflora was recorded in Southern Georgia (Manglisi), where nine different genera of microscopic fungi were found (Fig. 2). Similarities were observed between the mycoflora composition of Eastern and Southern Georgian brown soils: in both regions, the genera *Aspergillus*, *Penicillium*, *Fusarium*, *Rhizopus*, *Mucor*, and *Trichoderma* were present. Across all three regions, *Fusarium* and *Trichoderma* were common; *Mortierella* was absent only in Eastern Georgia. The genera *Cladosporium* and *Alternaria* were specific to Southern Georgia brown soils; *Actinomucor* was unique to Eastern Georgia, and *Acremonium* was specific to Western Georgia.

The ~~distinctiveness~~ of the mycoflora of Western Georgia brown soils compared to the other two regions may be explained by ~~the fact that~~ Bakhmaro's ~~is located at an~~ altitude of 2050 m.a.s.l. and is dominated by coniferous forests. Consequently, its soils are acidic; whereas Manglisi and Tskhvarichamia lie at similar elevations (1180–1200 m a.s.l.), and the soil samples for mycoflora analysis there were collected from comparable habitats—mixed forests. In contrast to Bakhmaro, Manglisi's mixed forest soils have a neutral pH.

It is generally known that mixed forests adapt more successfully to environmental changes than monocultures (Bravo-Oviedo et al., 2014). The coexistence of different tree species enhances nutrient uptake from the soil, promotes plant growth, and creates mutually supportive ecological niches. These niches contribute to the exceptional taxonomic richness of mixed forest ecosystems (Ishida et al., 2007; Cavard et al., 2011). Naturally, this is reflected in the diversity of fungal co-communities in mixed forest soils as well (Ishida et al., 2007; Nagati et al., 2018). The full spectrum of differing abiotic factors (vertical zonation, temperature, humidity, ~~and~~ soil pH) and the species composition of the phytocoenosis provided sufficient conditions for the formation of a distinct mycoflora in Bakhmaro brown soils.

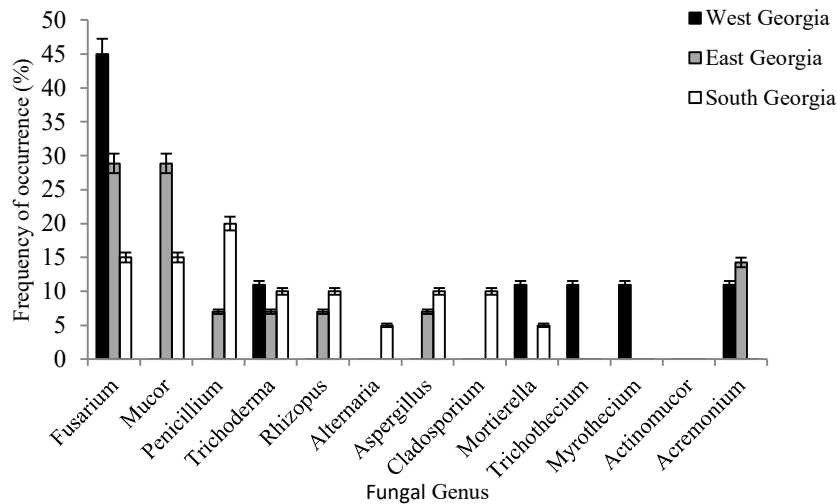


Fig. 2. Frequency of occurrence (%) of the genera of microscopic fungi in brown soils across different pedological regions of Georgia.

4. CONCLUSIONS

Based on the conducted research, the following conclusions were drawn:

The taxonomic structure of the mycoflora in the same soil types (alluvial and brown) ~~of~~ across Western, Eastern, and Southern Georgia is shaped by a combination of factors, including climatic conditions, microrelief, and the physico-chemical properties of the soil.

Comparative analysis of alluvial soil mycoflora revealed that the dominant genera common to all three regions are *Penicillium* and *Aspergillus*, which can be explained by their ecological plasticity and strong sporogenesis. The distribution of other taxa is closely related to the specific geoecological characteristics of each region. Xerotolerant genera are characteristic of Eastern Georgia, while the coexistence of ~~both~~ hygrophilous and xerophilous species in the Southern region is likely determined by ecotonal conditions.

Comparison of brown soil mycoflora showed that, despite general similarities, significant local specificities exist, mainly linked to topographic, botanical, and climatic heterogeneity. The highest taxonomic diversity was recorded in the soils of mixed forests in Southern Georgia, ~~which is~~ likely ~~explained by due to~~ their structurally rich, neutral pH soils. In contrast, the relatively low diversity of mycoflora in Western Georgia (Bakhmaro) is associated with acidic soils and ~~the a~~ monoculture coniferous forest cover.

The majority of mycoflora in Georgia's alluvial and brown soils belong to the phylum *Ascomycota*, while representatives of *Mucoromycota* and *Mortierellomycota* are present in comparatively smaller numbers.

The taxonomic structure of mycocommunities is largely determined by soil type and geographical location, further emphasizing the role of abiotic factors in shaping soil biocenoses.

5. COMPETING INTERESTS

Authors have declared that no competing interests exist.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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