

Current state of the species composition of mycobiota in South-East Kazakhstan

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Abstract. To date, no information has been available on the species composition of fungi in southeastern Kazakhstan, the center of agrobiodiversity but also home to rare and endemic species. Therefore, our objective was to investigate the diversity of fungi, fungus-like organisms, and lichens in southeastern Kazakhstan. The scientific and practical significance of the work is to obtain data on the species composition of mycobiota, which will allow planning measures for its monitoring, protection and restoration. The material for the article served as the authors' own collections, conducted in 2021-2023. The study and identification of fungi were carried out according to the standard methodology. In the study area 2864 species of fungi, fungus-like organisms and lichens from 3 kingdoms, 22 classes, 84 orders, 260 families and 770 genera were found. Among them, 36 species were new to southeastern Kazakhstan, and 8 species were new to Kazakhstan. It is worth noting that the Karasay region had the largest number of species (1547) when analyzing the distribution of fungi, fungus-like organisms, and lichens. The study's value and practical significance lies in the data obtained on the species composition of fungi, fungus-like organisms, and lichens, including their distribution and confinement to different types of substrates.

1 Introduction

Accounting and appropriate assessment of available natural resources are crucial for management decisions. The result of long-term accounting is usually a state cadastre, considered as a systematized set of data, an inventory of objects and phenomena, and representing a scientific basis for further long-term monitoring of the state of mycobiota within the study area, which will provide an opportunity to detect local changes in the components of the environment and will serve as a scientific basis for making informed management decisions regarding the biological resources of the country. At the same time, the identification and development of effective measures to protect and restore the number of rare species of fungi, as well as the implementation of environmental protection measures will be provided. The availability of up-to-date data on the species diversity of the plant world allows planning measures for their monitoring, protection and restoration.

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The territory of southeastern Kazakhstan, including the Balkhash and Ili region plains, mountain systems of the Northern Tien Shan and Dzungarian Alatau, is the center of concentration of not only agrobiodiversity, but also rare and endemic species of plants, fungi and lichens. At the same time, the actively developing agro-industrial complex has a negative impact on the state of the vegetation cover of the region. The consideration of the botanical diversity of the territory of southeastern Kazakhstan is consistent with international trends of modern scientific research in the field of inventory and conservation of biodiversity [1].

2 Materials and methods

Research of the territory of southeast Kazakhstan (Almaty and Zhetysu regions) was carried out by route method in 2021-2023. The attention was paid to the following plant damages: fungal plaques, pustules, spots, mummification, deformation and destruction of separate organs. All affected plants were photographed, collected and included in the herbarium. Each specimen was labeled with the location or habitat (necessarily with GPS coordinates of the point), date of collection and name of collectors, presumed species affiliation of the host plant (feeding plant).

Study and identification of fungi were carried out using standard methods [2]. Observation and photography were carried out using a Levenhuk MED D45T LSD light microscope at different magnifications (from 10^x to 100^x with oil immersion). Available identifiers for different groups of fungi were used to identify fungal species [3-6].

In addition to microscopic fungi, fruiting bodies of various macromycetes were collected. Species identification was carried out according to both national and foreign identifiers, monographic works on individual taxonomic groups of fungi [7, 8].

Lichen samples were collected along the route, living both on rocks, soil and sand, and on the bark of trees and shrubs, thin twigs of semi-shrubs. Species identification was based on morphological (life form; thallus color; presence of attachment organs; type, size and location of fruiting bodies on the thallus, etc.) and anatomical characters (thallus type, type and features of internal structure of fruiting bodies, shape and size of bags, type, color and size of spores, etc.) and chemical reactions specific for lichens. The staining was performed using 10% aqueous potassium hydrochloride solution, saturated aqueous calcium hypochloride solution and alcoholic iodine solution. Available identifiers were used to identify lichen species [9, 10].

Fungal species names and authors are given according to the Mycobank database [11], species names of feeding plants according to the Catalogue of life database [12].

3 Results and Discussion

In the course of mycological studies and in the analysis of literature data [13-16 etc.] it was found that 2864 species of fungi, fungus-like organisms and lichens from 3 kingdoms, 22 classes, 84 orders, 260 families and 770 genera are found in the territory of southeastern Kazakhstan (Table 1). The myxomycetes are represented by two classes, of which Protosteliomycetes Alexop. & Mims comprises one order, one family, one genus and one species *Ceratiomyxa fruticulosa* (O.F. Müll.) T. Macbr. From class Myxomycetes G. Winter 65 species from 4 orders, 7 families and 24 genera were found on the territory of south-east Kazakhstan. The most frequent species are *Lycogala epidendrum* (L.) Fr. and *Fuligo septica* (L.) F.H. Wigg on different substrates. It is necessary to mention the species *Diderma niveum* (Rostaf.) T. Macbr., appearing in early spring, immediately after snow melt.

The kingdom Chromista Caval.-Sm. is represented by four classes: Reronsporomycetes Locq. with 48 species parasitizing various plants; Oomycetes G. Winter with one species isolated from soil; Mucoromycetes Doweld with 17 soil species and Umbelopsidomycetes Tedersoo, Sanchez-Ramirez, Kõljalg, Bahram, M. Döring, Schigel, T.W. May, M. Ryberg & Abarenkov – with one species isolated from soil.

Table 1. Taxonomic structure of mycobiota of southeastern Kazakhstan.

Kingdom / Subkingdom / Division	Class	Quantity			
		orders	families	genera	species
Protozoa / Myxomycota	Myxomycetes	4	7	24	65
	Protosteliomycetes	1	1	1	1
Chromista / Oomycota	Peronosporomycetes	2	2	9	48
	Oomycetes	1	1	1	1
Mucoromycota	Mucoromycetes	1	3	6	17
	Umbelopsidomycetes	1	1	1	1
Fungi	<i>Insertae sedis</i>			2	2
/ Ascomycota	<i>Insertae sedis</i>		1	32	66
	Candelariomycetes	1	1	2	4
	Coniocybomycetes	1	1	1	1
	Dothideomycetes	13	42	148	900
	Eurotiomycetes	3	5	16	143
	Lecanoromycetes	12	28	86	214
	Leotiomycetes	3	14	54	202
	Pezizomycetes	2	13	31	55
	Sordariomycetes	16	48	116	286
	Taphrinomycetes	1	2	3	11
/ Basidiomycota	<i>Insertae sedis</i>			1	1
	Agaricomycetes	13	74	198	562
	Tremellomycetes	1	1	1	1
	Microbotryomycetes	1	1	3	7
	Pucciniomycetes	1	7	21	208
	Exobasidiomycetes	3	3	4	31
	Ustilaginomycetes	2	3	8	35
Zoopagomycota	Zoopagomycetes	1	1	1	2
Total		22	84	260	770
				2864	

The division Ascomycota Caval.-Sm. has 9 classes, among which the largest class is Dothideomycetes O.E. Erikss. with 900 species. From the class Sordariomycetes O.E. Erikss. & Winka, 286 species occur in the study area, some of them isolated from soil. The detected lichenized fungi belong to two classes of Lecanoromycetes O.E. Erikss. & Winka with 214 species, and Candelariomycetes Voglmayr & Jaklitsch with 4 species. In the class Leotiomycetes O.E. Erikss. & Winka, comprising 202 species, the most important are representatives of the family Erysiphaceae Tul. & C. Tul. – phytopathogens causing powdery mildew of various plants. 104 species of powdery mildew were found, most of which are characterized by a wide distribution. The class Eurotiomycetes O.E. Erikss. & Winka has 143 species, most of which are soil fungi.

Division Basidiomycota R.T. Moore is represented by 6 classes, among which the largest are Agaricomycetes Doweld with 562 species and Pucciniomycetes R. Bauer, Begerow, J.P. Samp., M. Weiss & Oberw. with 202 species. Representatives of the latter class are phytopathogens and cause rusts of various plants.

From the division Zoopagomycota Gryganskyi, M. E. Smith, Spatafora & Stajich discovered 2 species parasitizing representatives of mucor fungi.

In the territory of the study area 36 species new to southeastern Kazakhstan, including 1 species of myxomycetes (*Physarum cinereum* (Batsch) Pers. on *Picea schrenkiana* Fisch. & C.A. Mey.), 2 species of mucor fungi (*Cunninghamella echinulata* (Thaxt.) Thaxt. ex Blakeslee, *Lichtheimia corymbifera* (Cohn) Vuill.), 29 species of ascomycetes, 1 species of pucciniomycetes (*Puccinia burnettii* Griffiths (I) on *Krascheninnikovia ceratoides* (L.) Gueldenst.), 1 species of ustilaginomycetes (*Ustilago elytrigiae* Golovin on *Elymus repens* (L.) Gould); 2 species of Zoopagomycota (*Piptocephalis cylindrospora* Bainier, *Piptocephalis arrhiza* Tiegh. & G. Le Monn.).

Regarding the 29 ascomycete species, 4 of these are soil fungi (*Ramichloridium apiculatum* (J.H. Mill., Giddens & A.A. Foster) de Hoog, *Thermomyces dupontii* (Griffon & Maubl.) Houbraken & Samson, *Nodulisporium africanum* G. Sm., *Cordana bisbyi* (Timonin) Hern.-Restr., Gené & Guarro), 7 species are lichenized (*Acarospora cervina* A. Massal., *A. glypholecioides* H. Magn., *A. rugulosa* Körb., *A. strigata* (Nyl.) Jatta, *Lecanora goettweigensis* Zahlbr., *Romularia lurida* (Ach.) Timdal, *Circinaria maculata* (H. Magn.) Q. Ren). The remaining species inhabit the plant substrate: *Diplodia capparis* Koshk. & Frolov on *Capparis spinosa* var. *herbacea* (Willd.) Fici; *Guignardia dodartiae* Nasyrov ex Vasyag. on *Dodartia orientalis* L.; *Selenophoma alhagi* Vasyag. on *Alhagi pseudalhagi* subsp. *kirghisorum* (Schrenk) Yakovl.; *Selenophoma chondrillae* (Nikol.) Petr. on *Chondrilla* sp.; *Passalora ariae* (Fuckel) U. Braun & Crous on *Sorbus tianschanica* Rupr.; *Ramularia medicaginis* Bondartsev & Lebedeva on *Medicago* spp.; *Sphaerulina lini* Kalymb. on *Linum heterosepalum* Regel; *Phoma haloxylicola* Kravtzev on *Haloxyylon ammodendron* (C. A. Mey.) Bunge ex Fenzl; *Camarosporium ziziphorae* Schwarzman on *Ziziphora clinopodioides* Lam.; *Coniothyrium radiciperduum* Kravtzev on *Haloxyylon ammodendron* (C. A. Mey.) Bunge ex Fenzl; *Coniothyrium pyrinum* (Sacc.) J. Sheld. on *Malus* sp.; *Coniothyrium zygophylli* Syd. & P. Syd. on *Zygophyllum fabago* L.; *Paraconiothyrium lini* (Pass.) Verkley & Gruyter. on *Linum heterosepalum* Regel; *Pseudocamarosporium propinquum* (Sacc.) Wijayaw., Camporesi & K.D. Hyde on *Salix* sp.; *Venturia cerasi* Aderh. on *Prunus griffithii* (Boiss.) C. K. Schneid.; *Vermicularia acuminata* Schwein. on *Iris ruthenica* Ker Gawl., *Tulipa* sp.; *Cytospora spiraeae* X.L. Fan on *Spiraea hypericifolia* L.; *Libertella betulina* Desm. on *Betula pendula* Roth.

There are 7 new species of fungi recorded for Kazakhstan (*Phoma aceris-negundinis* Arcang. on *Acer negundo* L., *Stenocybe ahtii* Titov & Baibul. on *Lonicera stanantha* Pojark., *Heteropatella polygoni* Schwarzman on *Koenigia alpina* (All.) T. M. Schust. & Reveal (Fig. 1), *Trichoderma pararogersonii* Jaklitsch & Voglmayr, *Trichoderma rossicum* Bissett, C.P. Kubicek & Szakacs, *Libertella rosae* Desm. on *Spiraea* sp., *Cytidia salicina* (Fr.) Burt. on *Salix* sp. (Fig. 2) and 1 species of lichen (*Scytinium palmatum* (Huds.) Gray (*Leptogium palmatum* (Huds.) Mont.)).

During the analysis of fungi species distribution it should be noted that the largest number of species (1547) was found in Karasay district (Fig. 3), which is primarily due to the location of the Trans-Ili Alatau ridge, the most studied of all mountain systems, on the territory of the district. For the same reason, a significant number of species are counted in Enbekshikazakh (844) and Talgar (566) districts. Significantly fewer species of fungi and fungus-like organisms are found in Kegen (529), Kerbulak (405) and Sarkand (333) districts. Very few species were found in Karatal and Koksuy districts, the least studied of all.

Regarding the distribution of certain groups of fungi and fungus-like organisms in the study area, it can be noted that myxomycetes (classes Myxomycetes and Protosteliomycetes) are characteristic of mountainous areas of southeastern Kazakhstan (Enbekshikazakh, Zhambyl, Karasai, Kegen, Kerbulak, Talgar, Uygur) and completely

absent in desert areas. The same is observed for peronosporous fungi, which require high humidity for their development.

The most widespread classes are Dothideomycetes, Sordariomycetes and Pucciniomycetes, found in all 17 districts of southeastern Kazakhstan and on the territory of Konaev city.



Fig. 1. *Heteropatella polygoni* on *Koenigia* **Fig. 2.** *Cytidia salicina* on *Salix* sp. *alpinae*.

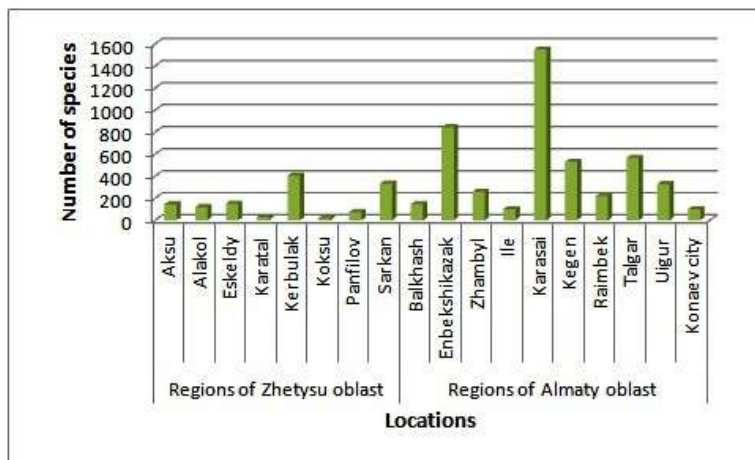


Fig. 3. Distribution of species of fungi, fungus-like organisms and lichens in southeastern Kazakhstan

Representatives of the class Leotiomycetes were not observed in the territory of Koksu district and are found in 16 districts of the region and in the territory of Konaev. Representatives of three classes were found in 15 districts of the region and in Konaev city. At the same time, species of class Eurotiomycetes were not found in Karatal and Panfilov districts; species of class Lecanoromycetes – in Eskeldy and Panfilov districts; species of class Agaricomycetes – in Koksuy and Panfilov districts.

4 Conclusion

In the study area 2864 species of fungi, fungus-like organisms and lichens from 3 kingdoms, 22 classes, 84 orders, 260 families and 770 genera were found. The vast majority of species (2731 species, 95% of the total number of species) belong to the kingdom Fungi. The kingdom Protozoa is represented by 66 species, the kingdom Chromista – by 67 species. The list of 36 species new to southeast Kazakhstan is given, of which 1 species is myxomycete, 2 species are mucor fungi, 29 species are ascomycetes, 1 species is pucciniomycetous, 1 species is ustilaginomycetous; 2 species are from Zoopagomycota. Eight species are new for Kazakhstan. The largest number of fungi, fungus-like organisms and lichens (1547) was found in the Karasay district, which is associated with the location of the Zailiysky Alatau ridge, the most studied of the mountain systems. Significant number of species are counted also in Enbekshikazakh (844) and Talgar (566) districts. A very small number of species was found in Karatal and Koksu districts. Myxomycetes and Peronospora fungi are characteristic for mountainous areas and are completely absent in desert areas. The most widely distributed classes are Dothideomycetes, Sordariomycetes and Pucciniomycetes, found in all 17 districts of southeastern Kazakhstan and on the territory of Konaev. The data obtained are important for planning activities to monitor the species composition of mycobiota.

Acknowledgments

The present work was carried out according to the results of scientific-technical program BR10264557 "Cadastral assessment of the current ecological state of flora and plant resources of Almaty region as a scientific basis for effective management of resource potential" (2021-2023).

Authors' contribution

Conceptualization, Y. Rakhimova and L. Kyzmetova; Methodology, A. Myrzakhan; Formal Analysis, G. Sytabekkyzy and A. Alikhanova; Investigation, L. Kyzmetova, G. Sytabekkyzy and A. Myrzakhan; Writing – Original Draft Preparation, L. Kyzmetova; Writing – Review & Editing, Y. Rakhimova.

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