

Original Research Paper

An Annotated Checklist of Powdery Mildew Fungi (*Erysiphaceae*) in the Ile-Alatau Mountains (within Kazakhstan)

^{1,2}G. Sypabekkyzy, ³T. Bulgakov, ⁴M. Sedlářová, ¹Y. Rakhimova, ¹L. Kyzmetova and ¹A. Assylbek

¹Institute of Botany and Phytointroduction, Almaty, Kazakhstan

²Al-Farabi Kazakh National University, Almaty, Kazakhstan

³Federal Research Centre the Subtropical Scientific Centre of the Russian Academy of Sciences, Sochi, Russia

⁴Palacký University Olomouc, Olomouc, Czech Republic

Article history

Received: 16-02-2023

Revised: 26-06-2023

Accepted: 13-07-2023

Corresponding Author:

A. Assylbek

Institute of Botany and
Phytointroduction, Almaty,
Kazakhstan

Email: a-asema-89@mail.ru

Abstract: The *Erysiphaceae* family is a diverse group of fungi with complex evolutionary relationships. All previous data for powdery mildew fungi in Ile-Alatau are outdated and needed to be revised due to changes in the *Erysiphaceae* taxonomy. The purpose of our research was to revise all data and to compile an actual checklist of *Erysiphaceae* in the Ile-Alatau based on revisions of the available fungal samples of the Herbarium Fund of the Institute of Botany and Phytointroduction of the Republic of Kazakhstan, the authors' own collections and a critical revision of the genera. Mycological survey of the territory of the Ile-Alatau was done by the route method during 2013-2020. An actual checklist of powdery mildews in the Ile-Alatau Mountains was compiled. The powdery mildews are represented by 91 species of 8 genera. The largest genus is *Erysiphe* containing 30 species and forms recorded on 99 angiosperm host plant species. The genera *Podospaera* and *Golovinomyces* have 20 and 17 species, respectively. Totally, 40 species were recorded as host plants for the first time, including 24 of them due to taxonomic revisions. The greatest number of species and forms of powdery mildews is noted at altitudes of 1200-2000 m above sea, in the forest belt of Ile-Alatau Mountains. Three most numerous genera-*Erysiphe*, *Golovinomyces*, *Podospaera*-prevail in all gorges and habitats. Five species were found on plants listed in the Red Book of Kazakhstan. The coefficient of similarity of the species composition of powdery mildew fungi on the territory of the Ketmen and Ile-Alatau ridges is 60%, while on the territory of the Terskey and Ile-Alatau ridges 70%. The value of the study and practical significance lies in obtaining data on the diversity of powdery mildew fungi in the Ile-Alatau Mountains, their location, distribution and association with the host.

Keywords: Fungal Biodiversity, Helotiales, High-Altitudinal Zone, Host Plant, Obligate Parasite, Plant Pathogenic Fungus

Introduction

Powdery mildew fungi (*Ascomycota*, *Leotiomycetes*, *Helotiales*, *Erysiphaceae*) are one of the most common and numerous taxa among plant pathogenic ascomycetous fungi (Braun, 2012). As obligate parasites of plants, powdery mildew fungi have been recorded in over 10,000 species of angiosperms (mainly dicotyledons) (Takamatsu, 2004; Braun, 2012), including such economically important agricultural crops and forest trees (Hückelhoven and Panstruga, 2011).

The taxonomy of the *Erysiphaceae* has undergone deep revisions since the beginning of 21st century (Braun, 2012; Johnston *et al.*, 2019), were the result of the use of new methods for studying the fungal genome, as well as electron microscopy of the morphological structures of fungi. The old genera *Microspora*, *Trichocladia* and *Uncinula* were included in the genus *Erysiphe* (Takamatsu *et al.*, 1999), the genus *Podospaera* was synonymized with genus *Podospaera* and some new genera like *Golovinomyces* (Qiu *et al.*, 2020), *Neoerysiphe* (Takamatsu *et al.*, 2008;

2007) and some other were established (Takamatsu *et al.*, 1999; Braun, 2012); many unclear complex species such as '*Erysiphe communis*', '*Golovinomyces cichoracearum*', '*Levellula taurica*', '*Phyllactinia suffulta*', '*Sphaerotheca fuliginea*' and some others have been revised and divided into several new species (Braun and Takamatsu, 2000; Takamatsu and Kano, 2001; Braun *et al.*, 2006).

The Central Asia (including Kazakhstan) is the one of the main centres of *Erysiphaceae* diversity, especially for the genera *Levellula*, *Phyllactinia* and *Podosphaera* (Braun, 2012). Powdery mildews were relatively well-studied in Kazakhstan in middle of 20th century (1940-1950s): Totally, 47 species and 307 variations of powdery mildew fungi and 565 host plant species of 285 genera were recorded the country at 1961 (Vasyagina *et al.*, 1961); among them 29 species and 145 forms of powdery mildews were known for Ile-Alatau mountains.

Further researches on the mycobiota of Ile-Alatau were summarized in the later monograph (Kalymbetov, 1969), according to which the number of *Erysiphaceae* species in Ile-Alatau was 57 species and 221 forms of *Erysiphaceae* (or 53 species-by later taxonomic revisions). However, now we can consider these numbers to be significantly overestimated, since the monograph includes many taxa that were found not in Ile-Alatau only, but also in adjacent areas, such as the mountains of Syugaty, Boguty, Turaigyr, Ketmen and Kungei.

The total revision of all available data was made in 2013. At that time 710 additional specimens of powdery mildew fungi that were collected and inserted in the mycological herbarium of the Institute of Botany after the publication of the third volume of the 'Flora of Spore Plants of Kazakhstan' (Vasyagina *et al.*, 1961), including the specimens collected by the authors during field researches. The checklist of *Erysiphaceae* species (taking into account changes in the taxonomy) was compiled in 2013. There were 81 species and 25

variations of powdery mildews known in Kazakhstan at that time (Rakhimova *et al.*, 2013) and 739 plant species of 305 genera were listed as host plants, including 122 species recorded as host plants for the first time.

However, all previous data for powdery mildew fungi in Ile-Alatau are outdated and needed to be revised due to changes in the *Erysiphaceae* taxonomy. The purpose of our research was to revise all data and to compile an actual checklist of *Erysiphaceae* in the Ile-Alatau based on the available old fungal samples of the Herbarium of the Institute of Botany and Phytointroduction of the Republic of Kazakhstan, the authors' own collections and other available data. The study consists of five sections, namely the introduction, materials and methods, results, discussion and conclusion.

Materials and Methods

Location of the Study

Ile-Alatau Mountains is the northernmost part of the Tien Shan Mountains, located in the south-east of southeastern part of Kazakhstan (Fig. 1). Its length from west to east is almost 380 km, the width-30-40 km, the height-up to 5000 m above sea level. The northern slope is strongly dissected into many gorges and smaller side ridges. The rivers Uzyn-Kargaly, Chemolgan, Aksai, Kaskelen, Big and Small Almaty, Issyk, Turgen flow down from the northern slope, forming deep gorges. The southern slope of the ridge is very steep and short, dissected by short valleys of rivers.

The climate of the Ile-Alatau is continental, differentiated by high-altitude climatic zones. The average annual temperature varies from +7.5°C at an altitude of 900-1500 m above sea level to -2°C at an altitude of 2700-3500 m above sea level.

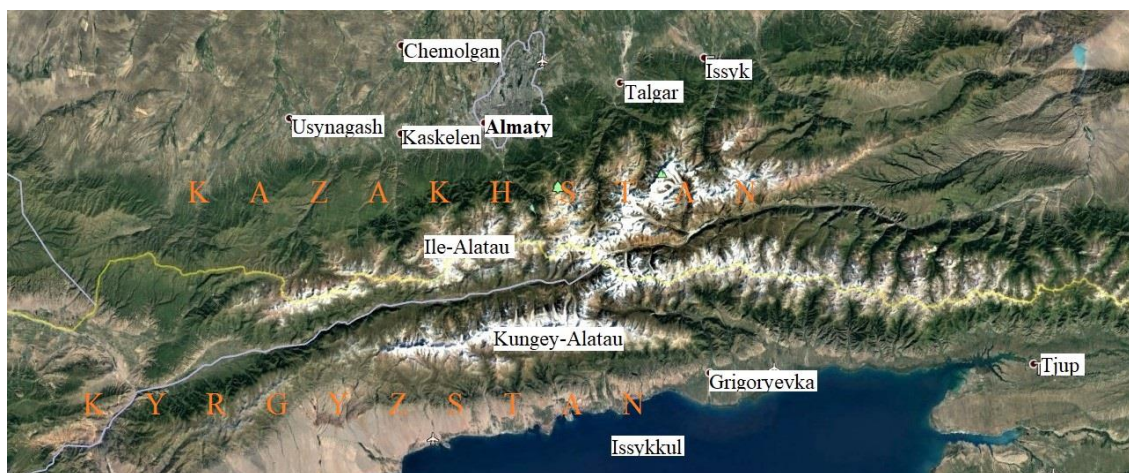


Fig. 1: Map showing the location of the research area

Vegetation is characterized with specific spectrum of altitudinal belts: Dzungar-Northern Tien Shan group of zonation types, including foothill deserts (700-800 m above sea level), steppes (800-1400 m), small-leaved forests (1400-1700 m), coniferous forests and meadows (1700-2300 m), subalpinotype meadows and dwarf forests (2300-2800 m), cryophytic (alpinotypic) meadows and local meadows dominated by species of the genus *Kobresia* Willd. (2800-3300 m) and subnival vegetation (3300-3600 m above sea level) (Rachkovskaya *et al.*, 2003). There is no distinct belt of coniferous forests and the belt of alpine tundra in Ile-Alatau and all subtypes of mountain steppes are widespread throughout the mountains.

Mycological Survey

Mycological survey of the territory of the Ile-Alatau (Fig. 1) was done by the route method during many years (2013-2020).

The listed gorges of the main ridge of the Ile-Alatau were surveyed:

- Ayusai (1776 m a. s. l., 43°05'45.5"N, 76°56'40.0"E; 1888 m a. s. l., 43°05'18.4"N, 76°56'46.2"E)
- Big Almaty (1442 m a. s. l., 43°06'80.1"N, 76°54'54.3"E, 2563 m a. s. l., 43°03'28.9"N, 76°59'18.3"E)
- Butakov (1728 m a. s. l., 43°11'00.3"N, 77°04'52.2"E; 1789 m a. s. l., 43°10'45.9"N, 77°05'13.3"E)
- Issyk (1761 m a. s. l., 43°14'43.1"N, 77°28'35.7"E; 43°15'35.7"N, 77°29'10.1"E)
- Kaskelen (1313 m a. s. l., 43°06'23.8"N, 76°36'35.6"E; 1846 m a. s. l., 43°01'56.2"N, 76°36'98.9"E)
- Kuznezov (1517 m a. s. l., 43°21'98.5"N, 77°40'46.5"E; 1588 m a. s. l., 43°21'32.6"N, 77°40'94.8"E)
- Small Almaty (1647 m a. s. l., 43°09'34.9"N, 77°01'57.0"E; 3153 m a. s. l., 43°06'91.9"N, 77°01'98.1"E)
- Monk (1526 m a. s. l., 43°21'63.1"N, 77°40'68.1"E)
- Oi-Karagai (1866 m a. s. l., 43°51'68.0"N, 77°07'65.2"E)
- Prokhodnoye (1801 m a. s. l., 43°05'27.3"N, 76°54'22.3"E; 2731 m a. s. l., 43°02'58.8"N, 76°55'06.8"E)
- Talgar (1071 m a. s. l., 43°16'89.6"N, 77°13'08.3"E; 1171 m a. s. l., 43°15'23.1"N, 77°12'92.1"E)
- Ters-Butak (1642 m a. s. l., 43°07'91.4"N, 76°57'03.9"E)
- Turgen (1344 m a. s. l., 43°31'64.6"N, 77°38'45.5"E; 2456 m a. s. l., 43°13'07.6"N, 77°48'34.9"E)
- Uzyn-Kargaly (1198 m a. s. l., 43°06'85.1"N, 76°26'01.7"E)

- Chemolgan (1305 m a. s. l., 43°07'11.7"N, 76°33'96.3"E)
- Ush-Konyr (1233 m a. s. l., 43°07'35.4"N, 76°30'81.5"E)
- Zhetyzhol ridge, Besmoinak (1801 m a. s. l., 43°06'11.6"N, 75°38'24.5"E; 2001 m a. s. l., 43°06'35.6"N, 75°36'28.5"E)
- Zhetyzhol ridge, gorge southwest of the village Akterek (1113 m a. s. l., 43°15'17.1"N, 75°24'24.5"E; 1129 m a. s. l., 43°15'14.2"N, 75°24'19.6"E)
- Kastek ridge, Karakastek gorge (1353 m a. s. l., 43°02'08.6"N, 76°04'01.5"E)
- Kastek ridge, Kastek gorge, (1381 m a. s. l., 43°01'53.0"N, 75°59'16.8"E; 2036 m a. s. l., 42°59'08.0"N, 78°50'04.9"E)

Collection of herbarium material, drying, packing, preparation and study of fungi using a was made according to standard methods of mycology and plant pathology for powdery mildews (Braun, 2012). Optical microscopy of the specimens was made using by Polyvar photomicroscope with Nomarski interference optics. *Erysiphaceae* species were identified using several actual keybooks for *Erysiphaceae* (Vasyagina *et al.*, 1961; Braun, 2012). The host plants were determined by Plantarium (2007-2023).

Data Analysis

The taxonomic list of powdery mildew species, which included the collections of the authors and literature data, was compiled using the fundamental taxonomic manual of *Erysiphaceae* (Braun, 2012) with additions for the several taxonomic revisions of the species complexes: *Blumeria graminis* (Liu *et al.*, 2021; Heluta, 2022), *Erysiphe adunca* (Darsaraei *et al.*, 2021), *E. loniceriae* (Bradshaw *et al.*, 2021), *Golovinomyces biocellatus* (Scholler *et al.*, 2016), *G. cynoglossi* (Braun *et al.*, 2018), *G. orontii* (Braun *et al.*, 2019), *Podosphaera tridactyla* (Meeboon *et al.*, 2020; Smith *et al.*, 2021), *P. cerasi* and *P. prunicola* (Moparathi *et al.*, 2019); *Leveillula taurica* (Khodaparast *et al.*, 2001; 2012). All names of host plant species are given by the open database "Catalogue of life" (Catalogue of Life Database, 2022).

Our data on the species composition of powdery mildew fungi in Ile-Alatau were compared with data on the Ketmen and Terskey Alatau ridges, using the coefficient of similarity of the species composition (Sørensen-Chekanovsky coefficient).

Results

The compiled checklist of powdery mildew species is arranged alphabetically by names of genera and species (Appendix). Short notes are provided for some taxa.

The Numbers of Powdery Mildews and their Host Plants in the Ile-Alatau Analysis

The checklist of powdery mildew fungi in the Ile-Alatau includes 91 species (Table 1), including 20 species that can be considered as new for the Ile-Alatau due to taxonomic revisions of complex species: *Blumeria bulbiger*, *B. dactylidis*, *B. graminicola*, *Erysiphe baeumleri*, *E. caprea*, *E. mayorii*, *Golovinomyces monardae*, *G. tabaci*, *Leveillula jaczewskii*, *L. lactucarum*, *L. picridis*, *L. rutae*, *Neoerysiphe hiratae*, *Phyllactinia betulae*, *P. fraxini*, *P. hippophaës*, *P. populi*, *P. pyri-serotinae*, *Podosphaera fuliginea*, *P. phtheirospermi*.

The largest genus is *Erysiphe* containing 30 species found on 99 species of angiosperms. The genera *Podosphaera* and *Golovinomyces* are represented by 20 and 17 species found on 62 and 59 host plant species, respectively. Despite the fact that the genus *Leveillula* is represented only by 10 species, the list of its host plant includes 36 species and many hosts are common to both any *Leveillula* species and one or two powdery mildew species of other *Erysiphaceae* genera (usually *Erysiphe* and *Podosphaera*).

Totally, 40 species were recorded for the first time as host plants in the territory of Ile-Alatau and 24 species can be treated as newly recorded due to the taxonomic changes. *Blumeria* species were first found on *Calamagrostis arundinacea*, *Elymus sibiricus*, *E. uralensis* and *Milium effusum*. *Erysiphe* species were first recorded on *Alyssum dasycarpum*, *A. szovitsianum*, *Anthriscus sylvestris*, *Betula pendula* subsp. *pendula*, *Catolobus pendula*, *Hylotelephium ewersii*, *Pseudoclausia turkestanica*, *Thalictrum simplex* and *Thlaspi arvense*. *Golovinomyces* species were first time found on *Eriophyton lamiiflorum*, *E. oblongatum*, *Eriophyton* sp., *Lactuca tianschanica*, *Myosotis alpestris*, *Stizolophus balsamita*, *Tanacetum parthenium* and *Tragopogon capitatus*. *Leveillula* species were first recorded on *Artemisia gmelinii*, *Echinops sphaerocephalus*, *Epilobium angustifolium*, *Hypericum hirsutum*. *Neoerysiphe* species were found for the first time on three new host plants: *Dracocephalum imberbe*, *Nepeta nuda* L. subsp. *nuda* and *Phlomis herba-venti* L. subsp. *pungens* and *Phyllactinia* species on one new host plant-*Crataegus chlorocarpa*. *Podosphaera* species were recorded for the first time on *Agrimonia eupatoria* subsp. *asiatica*, *Crataegus* × *dsungarica*, *Epilobium cylindricum*, *Euphorbia esula* subsp. *tommasiniana*, *Geranium linearilobum*, *Lomelosia songarica*, *Pedicularis anthemifolia* subsp. *elatior*, *Prunus padus* L. subsp. *padus*, *Prunus prostrata* var. *concolor*, *Ribes uva-crispa* var. *sativum* and *Veronica chamaedrys*.

Numbers of Powdery Mildew Species in the Gorges of Ile-Alatau

The highest species diversity of powdery mildews (61 species of 8 genera) was recorded in the small almaty gorge the largest one in the Ile-Alatau (Fig. 2). This gorge is the best studied, since it is located in close proximity to the city of Almaty and is constantly available for visiting. The second *Erysiphaceae* species diversity was recorded in the big almaty gorge-32 species of 7 genera. The three largest genera *Erysiphe*, *Golovinomyces*, *Podosphaera* prevail over other genera by species number in all gorges, excluding the Akterek and Besmoynak gorges of the Zhetyzhol ridge, where the lowest diversity of *Erysiphaceae* was recorded. This fact can be explained by the general low diversity of powdery mildew due to the much lower plant species diversity because of the drier local climate of these gorges (Fig. 2).

Almost a half (43 species) of all powdery mildews found in Ile-Alatau can be considered as rare species. Some of them, such as *Erysiphe celtidis*, *E. atraphaxis*, *E. umbilici*, *Phyllactinia fraxini* and a few others, are associated with rare host plants. Some other rare powdery mildews are found only on weeds (*Dodartia orientalis*, *Hyoscyamus niger*, *Sophora alopecuroides* and *Xanthium strumarium*) or cultivated plants (*Citrullus lanatus* and *Ribes uva-crispa* var. *sativum*), which are rare crops for Ile-Alatau. Two powdery mildews are associated with non-rare host plants, but those plant species are confined to specific soil habitats-rare and not typical for Ile-Alatau: *Erysiphe limonii* on *Limonium gmelinii*, which is confined to saline soils and *Leveillula cylindrospora* on *Krascheninnikovia ceratoides*, which is confined to sands and sandy loamy soils of foothill plains.

Table 1: The numbers of powdery mildews and their host plants in the Ile-Alatau

Powdery mildews		
Genus name	Number of species	Number of host plant species and subspecies
<i>Blumeria</i>	4	19
<i>Erysiphe</i>	30	99
<i>Golovinomyces</i>	17	59
<i>Leveillula</i>	10	36
<i>Neoerysiphe</i>	3	22
<i>Phyllactinia</i>	6	7
<i>Podosphaera</i>	20	63
<i>Sawadaea</i>	1	1
Total	91	306

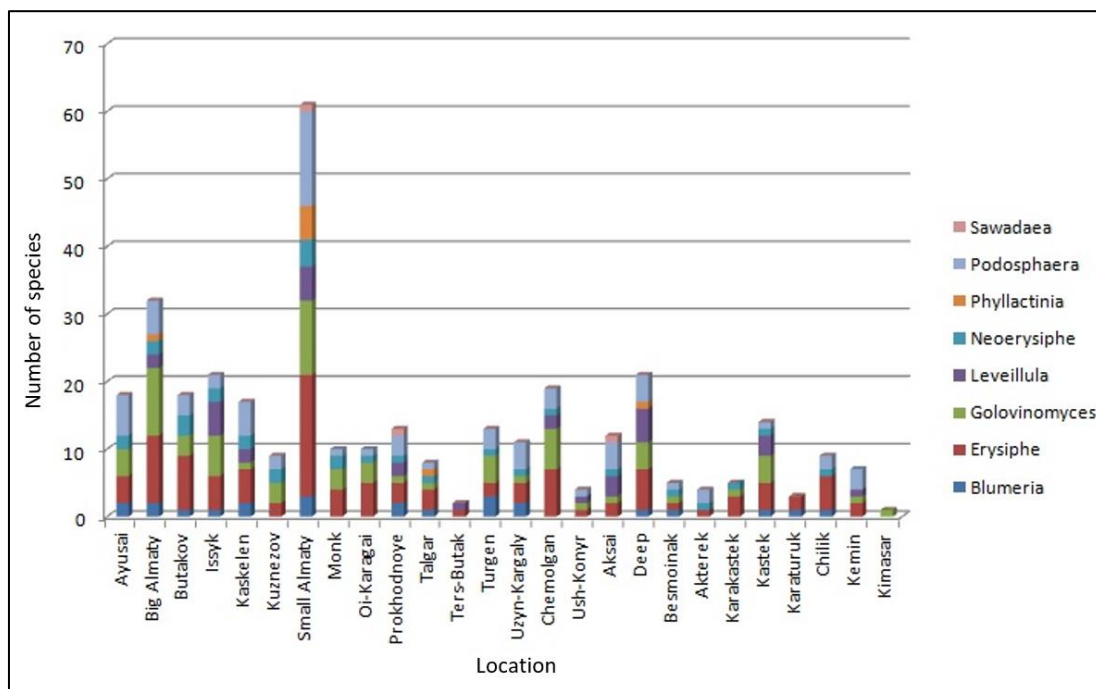


Fig. 2: Numbers of powdery mildew species in the gorges of Ile-Alatau

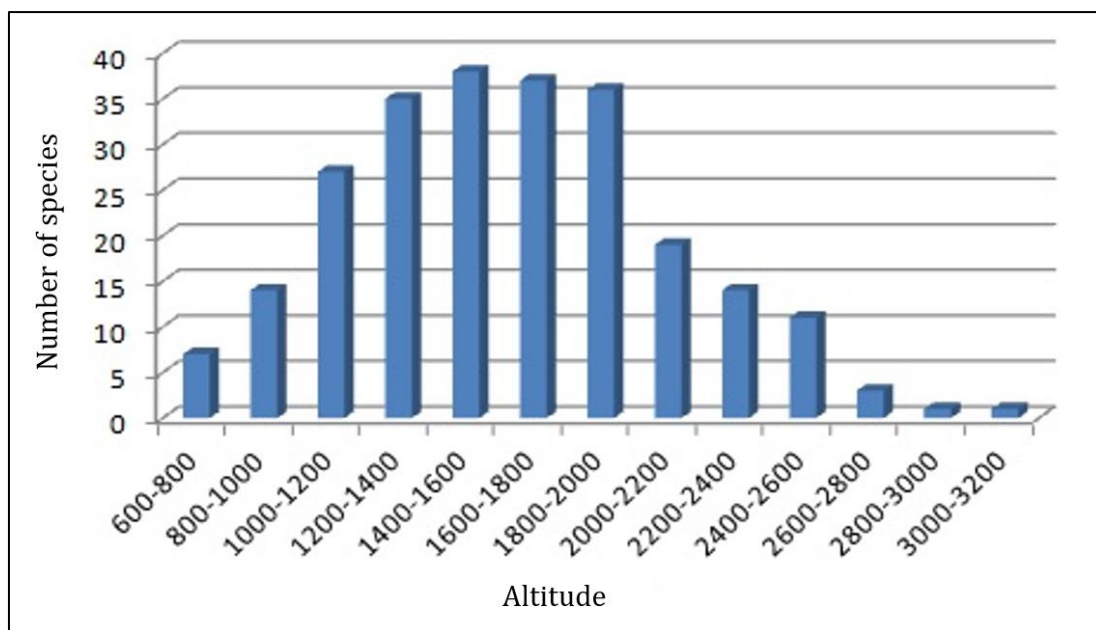


Fig. 3: The number of powdery mildew species in the high-altitude zones of Ile-Alatau

The Number of Powdery Mildew Species in the High-Altitude Zones of Ile-Alatau

The distribution curve of species numbers of powdery mildew in high-altitudinal zones of Ile-Alatau mountains has only one main peak (Fig. 3). The largest

number of species (35-38 species) is observed in plant communities at altitudes of 1200-000 m above sea level, which corresponds to the upper part of the steppe belt and the belts of small-leaved and dark coniferous forests. The species diversity of powdery mildew fungi in the foothill deserts and the subalpine belt is much

lower-only a few species have been found there. Thus, this pattern mainly reflects the highest diversity of host plants in the forest belt of Ile-Alatau.

Five species were found on plants listed in the Red Book of Kazakhstan: *Erysiphe atraphaxis* on *Atraphaxis muschketowii*, *Erysiphe celtidis* on *Celtis caucasica*, *Erysiphe hypophylla* on *Quercus robur*, *Phyllactinia fraxini* on *Fraxinus sogdiana*, *Podosphaera leucotricha* on *Malus sieversii*.

Discussion

The Ile-Alatau powdery mildews checklist presented in the article includes 91 species from eight genera. Comparing our data with the results of previous studies, we can note an increase in the number of powdery mildew species in the territory of Ile-Alatau: From 29 species (Vasyagina *et al.*, 1961), to 53 species (Kalymbetov, 1969) and further to 81 species (Rakhimova *et al.*, 2013). Such changes are associated primarily with the completeness of the mycological studies carried out on this territory and not with changes in the ecological situation. It should be noted that the creation of the Almaty Reserve in 1931 and the Ile-Alatau National Park in 1996 contribute to the preservation of the ecological situation in Ile-Alatau.

Over the past 10 years, the list of powdery mildew fungi has increased by another 20 species, which can be considered as new for the Ile-Alatau due to taxonomic revisions of the species complexes: *Blumeria graminis* (Liu *et al.*, 2021; Heluta, 2022), *Erysiphe adunca* (Darsaraei *et al.*, 2021), *E. loniceriae* (Bradshaw *et al.*, 2021), *Golovinomyces biocellatus* (Scholler *et al.*, 2016), *G. cynoglossi* (Braun *et al.*, 2018), *G. orontii* (Braun *et al.*, 2019), *Podosphaera tridactyla* (Meeboon *et al.*, 2020; Smith *et al.*, 2021), *P. cerasi* and *P. prunicola* (Moparthi *et al.*, 2019), *Leveillula taurica* (Khodaparast *et al.*, 2001; 2012).

Ile-Alatau belongs to the group of ridges of the Northern Tien Shan, which also includes Kungei Alatau and Ketmen. Ketmen is located to the east of Ile-Alatau. Kungei Alatau is located to the south of Ile-Alatau and

both ridges are almost parallel to each other. Further south is the Terskey Alatau ridge, which already belongs to the Central Tien Shan. Unfortunately, there are no data on the mycobiota of the Kungei Alatau ridge in the literature. The species composition of the mycobiota of the Ketmen ridge includes 42 species of powdery mildew fungi (Rakhimova *et al.*, 2017) (Table 2), all of which are also noted in the territory of the Ile-Alatau. The coefficient of similarity of the species composition (Sørensen-Chekanovsky coefficient) of powdery mildew fungi on the territory of the Ketmen and Ile-Alatau ridges is 60%. There is a detailed report by Domashova (1960) on the mycobiota of the Terskey Alatau ridge, which includes 50 species of powdery mildew fungi. It should be noted, that 21 forms of fungi mentioned by Domashova (1960) are not presented in the Index Fungorum database (2022) as legitimate. The coefficient of similarity of the species composition of powdery mildew fungi on the territory of the Terskey and Ile-Alatau ridges is 70%. 28 species of powdery mildew fungi are common to all three ranges. The leading genera on the territory of the Ile-Alatau and the ketmen ridges (Northern Tien Shan) are *Erysiphe*, *Podosphaera*, *Golovinomyces* (in descending order of the number of species), on the territory of Terskey Alatau (Central Tien Shan) *Erysiphe*, *Golovinomyces*, *Podosphaera* (Table 2).

In Terskey Alatau, the greatest diversity of powdery mildew fungi was noted in the foothill plain and low mountains (Domashova, 1960). In our studies, the largest number of species (35-38 species) is observed in plant communities at altitudes of 1200-2000 m above sea level, which corresponds to the upper part of the steppe belt and the belts of small-leaved and dark coniferous forests. Species of genera *Erysiphe*, *Blumeria* and *Leveillula* predominate in the foothills and low mountains. Species of the genus *Blumeria* have been recorded on the species *Bromus*, *Poa* and *Aegilops*. Of the genus *Erysiphe*, *Erysiphe atraphaxis*, *E. betae*, *E. celtidis*, *E. limonii*, *E. sophorae* were found only in the foothills and low mountains. Species of the genus *Leveillula* have been recorded on *Krascheninnikovia ceratoides*, on *Lagochilus* species, on *Dodartia orientalis*, *Chondrilla* sp., *Haplophyllum* sp.

Table 2: The numbers of powdery mildews in the Ile-Alatau, Ketmen and Terskey Alatau ridges

Genus name	Number of species		
	Ile-Alatau	Ketmen (Rakhimova <i>et al.</i> , 2017)	Terskey alatau (Domashova, 1960)
<i>Blumeria</i>	4	2	2
<i>Erysiphe</i>	30	13	19
<i>Golovinomyces</i>	17	8	11
<i>Leveillula</i>	10	4	7
<i>Neoerysiphe</i>	3	2	1
<i>Phyllactinia</i>	6	1	1
<i>Podosphaera</i>	20	12	9
<i>Sawadaea</i>	1	-	-

Small-leaved (1400-1700 m) and spruce (1700-2300 m) forests of Ile-Alatau, Terskey Alatau and Ketmen are characterized by species of the genera *Phyllactinia* and *Podosphaera* parasitizing shrubs and woody plants (Domashova, 1960; Rakhimova *et al.*, 2017). It should be noted that only *Leveillula picridis*, observed on *Artemisia dracunculus* in Ile-Alatau, rises to an altitude of 1500 m a. s. l. Only in Ile-Alatau, the species *Sawadaea bicornis* was found on the leaves of the invasive *Acer negundo*. In the forests, the proportion of species of the genus *Podosphaera* increases, since they are less demanding on the temperature regime (Domashova, 1960). The species *Erysiphe umbilici* on *Hylotelephium ewersii*, characteristic of Ile and terskey Alatau, is found on rock outcrops (Domashova, 1960).

Starting from the upper boundary of the forest belt and in the subalpine belt, the number of powdery mildew fungi decreases sharply. Moreover, there are no species characteristic only of subalps (Domashova, 1960). All species found in this belt, such as *Erysiphe aquilegiae* on *Aconitum rotundifolium*, *Podosphaera codonopsidis* on *Codonopsis clematidea*, *Podosphaera aphanis* on *Alchemilla* spp., are also widespread in other belts.

In the alpine and subnival belts, only one species was observed each. In Terskey and Ile-Alatau, the maximum altitude limit for the distribution of powdery mildew fungi is 3300 m a. s. l.

The most favorable season for the development of powdery mildew fungi is the second half of summer and early autumn. Few species are characteristic of spring: *Blumeria bulbiger* on *Bromus* species and *Podosphaera leucotricha* on *Malus sieversii*.

Conclusion

The conducted comparative study showed an increase in the number of species of powdery mildew. We believe that the reason for this is a thorough analysis of the collected data compared to previous studies, since there has been no improvement in the ecological situation on the territory of the Ile-Alatau Mountains over the past years.

The value of the study and practical significance lies in obtaining data on the diversity of powdery mildew fungi in the Ile-Alatau Mountains, their location, distribution and association with the host. The further prospects of our research should, with an increase in the types of powdery mildew, affect the safety of plants listed in the Red Book.

Acknowledgment

The authors thank the reviewers for their contribution to the peer evaluation of this study.

Funding Information

The research was financially supported by the scientific and technical program “Cadastral assessment of the current ecological state of the flora and plant resources of the Almaty region as a scientific basis for the effective management of resource potential” (BR10264557).

Author’s Contributions

All authors equally contributed in this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues are involved.

References

- Bradshaw, M., Braun, U., Götz, M., & Takamatsu, S. (2021). Taxonomy and phylogeny of the *Erysiphe lonicerae* complex (*Helotiales*, *Erysiphaceae*) on *Lonicera* spp. *Fungal Systematics and Evolution*, 7(1), 49-65. <https://doi.org/10.3114/fuse.2021.07.03>
- Braun, U. (2012). Taxonomic manual of Erysiphales (powdery mildews). *CBS Biodiversity Series*, 11. pp: 707, ISBN: 10-9789070351892.
- Braun, U., & Takamatsu, S. (2000). Phylogeny of *Erysiphe*, *Microsphaera*, *Uncinula* (*Erysiphaceae*) and *Cystotheca*, *Podosphaera*, *Sphaerotheca* (*Cystothecaceae*) inferred from rDNA ITS sequences: Some taxonomic consequences. *Schlechtendalia*, 4, 1-33. <http://doi.org/10.25673/90008>
- Braun, U., Bradshaw, M., Zhao, T. T., Cho, S. E., & Shin, H. D. (2018). Taxonomy of the *Golovinomyces cynoglossi* complex (*Erysiphales*, *Ascomycota*) disentangled by phylogenetic analyses and reassessments of morphological traits. *Mycobiology*, 46(3), 192-204. <https://doi.org/10.1080/12298093.2018.1509512>
- Braun, U., Shin, H. D., Takamatsu, S., Meeboon, J., Kiss, L., Lebeda, A., ... & Götz, M. (2019). Phylogeny and taxonomy of *Golovinomyces orontii* revisited. *Mycological Progress*, 18, 335-357. <https://doi.org/10.1007/s11557-018-1453-y>
- Braun, U., Takamatsu, S., Heluta, V., Limkaisang, S., Divarangkoon, R., Cook, R., & Boyle, H. (2006). Phylogeny and taxonomy of powdery mildew fungi of *Erysiphe* sect. *Uncinula* on *Carpinus* species. *Mycological Progress*, 5, 139-153. <https://doi.org/10.1007/s11557-006-0509-6>
- Catalogue of Life Database. (2022). <https://www.catalogueoflife.org>

- Darsaraei, H., Khodaparast, S. A., Takamatsu, S., Abbasi, M., Asgari, B., Sajedi, S., ... & Braun, U. (2021). Phylogeny and taxonomy of the *Erysiphe adunca* complex (*Erysiphaceae*, *Helotiales*) on poplars and willows. *Mycological Progress*, 20, 517-537. <https://doi.org/10.1007/s11557-021-01688-7>
- Domashova, A. A. (1960). *Mycoflora of the Terskey Ala-Too Ridge of the Kirghiz SSR*. Publishing House of the Academy of Sciences of the Kirghiz SSR, Frunze, pp, 246 (in Russian).
- Heluta, V. P. (2022). A critical revision of the powdery mildew fungi (*Erysiphaceae*, *Ascomycota*) of Ukraine: *Arthrocladiella* and *Blumeria*. *Ukrainian Botanical Journal*, 79(4), 205-220. <https://doi.org/10.15407/ukrbotj79.04.205>
- Hückelhoven, R., & Panstruga, R. (2011). Cell biology of the plant–powdery mildew interaction. *Current Opinion in Plant Biology*, 14(6), 738-746. <https://doi.org/10.1016/j.pbi.2011.08.002>
- Index Fungorum Database. (2022). <http://www.indexfungorum.org/names/names.asp>
- Johnston, P. R., Quijada, L., Smith, C. A., Baral, H. O., Hosoya, T., Baschien, C., ... & Townsend, J. P. (2019). A multigene phylogeny toward a new phylogenetic classification of Leotiomycetes. *IMA Fungus*, 10, 1-22. <https://doi.org/10.1186/s43008-019-0002-x>
- Kalymbetov, B. K. (1969). *Mycological flora of the Trans Ili-Alatau (Northern Tien Shan)*. Nauka, Alma-Ata, pp: 470.
- Khodaparast, S. A., Takamatsu, S., & Hedjaroude, G. A. (2001). Phylogenetic structure of the genus *Leveillula* (*Erysiphales*: *Erysiphaceae*) inferred from the nucleotide sequences of the rDNA ITS region with special reference to the *L. taurica* species complex. *Mycological Research*, 105(8), 909-918. <https://doi.org/10.1016/S0953-7562%2808%2961946-2>
- Khodaparast, S. A., Takamatsu, S., Harada, M., Abbasi, M., & Samadi, S. (2012). Additional rDNA ITS sequences and its phylogenetic consequences for the genus *Leveillula* with emphasis on conidium morphology. *Mycological Progress*, 11, 741-752. <http://dx.doi.org/10.1007/s11557-011-0785-7>
- Liu, M., Braun, U., Takamatsu, S., Hambleton, S., Shoukouhi, P., Bisson, K. R., & Hubbard, K. (2021). Taxonomic revision of *Blumeria* based on multi-gene DNA sequences, host preferences and morphology. *Mycoscience*, 62(3), 143-165. <https://doi.org/10.47371/mycosci.2020.12.003>
- Meeboon, J., Takamatsu, S., & Braun, U. (2020). Morpho-phylogenetic analyses revealed that *Podospaera tridactyla* constitutes a species complex. *Mycologia*, 112(2), 244-266. <https://doi.org/10.1080/00275514.2019.1698924>
- Mieslerová, B., Kitner, M., Petřeková, V., Dvořáková, J., Sedlářová, M., Cook, R. T., & Lebeda, A. (2020). *Golovinomyces* powdery mildews on Asteraceae in the Czech Republic. *Plant Protection Science*, 56(3), 163-179. <https://doi.org/10.17221/129/2019-PPS>
- Moparthi, S., Grove, G. G., Pandey, B., Bradshaw, M., Latham, S. R., Braun, U., ... & Romberg, M. (2019). Phylogeny and taxonomy of *Podospaera cerasi*, sp. nov., and *Podospaera prunicola* sensu lato. *Mycologia*, 111(4), 647-659. <https://doi.org/10.1080/00275514.2019.1611316>
- Plantarium. (2007-2023). Plants and lichens of Russia and neighboring countries: Open online galleries and plant identification guide. <https://www.plantarium.ru/lang/en.html>
- Qiu, P. L., Liu, S. Y., Bradshaw, M., Rooney-Latham, S., Takamatsu, S., Bulgakov, T. S., ... & Braun, U. (2020). Multi-locus phylogeny and taxonomy of an unresolved, heterogeneous species complex within the genus *Golovinomyces* (*Ascomycota*, *Erysiphales*), including *G. ambrosiae*, *G. circumfusus* and *G. spadiceus*. *BMC Microbiology*, 20, 1-16. <https://doi.org/10.1186/s12866-020-01731-9>
- Rachkovskaya, E. I., Volkova, E. A., & Khramtsov, V. N. (Eds.). (2003). *Botanical geography of Kazakhstan and Central Asia (within the desert region)*. St. Petersburg. pp: 424, ISBN: 10-5-201-11116-5.
- Rakhimova, Y. V., Nam, G. A., & Yermekova, B. D. (2013). Key to identifying powdery mildew fungi in Kazakhstan by families and genera of host plants. *Turchaninowia*, 16(1), 176-196. <http://turczaninowia.asu.ru/article/view/736>
- Rakhimova, Y. V., Nam, G. A., Yermekova, B. D., Jetigenova, U. K., Kyzmetova, L. A., & Yessengulova, B. Zh. (2017). *Diversity of fungi in the desert lowlands of the south-east of Kazakhstan and the Ketmen ridge*. Luxe Media, Almaty. pp, 300, ISBN: 10-9786017511371.
- Scholler, M., Schmidt, A., Siahaan, S. A. S., Takamatsu, S., & Braun, U. (2016). A taxonomic and phylogenetic study of the *Golovinomyces biocellatus* complex (*Erysiphales*, *Ascomycota*) using asexual state morphology and rDNA sequence data. *Mycological Progress*, 15, 1-13. <https://doi.org/10.1007/s11557-016-1197-5>
- Smith, R. L., May, T. W., Kaur, J., Sawbridge, T. I., Mann, R. C., Pascoe, I. G., & Edwards, J. (2021). Re-evaluation of the *Podospaera tridactyla* species complex in Australia. *Journal of Fungi*, 7(3), 171. <https://doi.org/10.3390/jof7030171>
- Takamatsu, S. (2004). Phylogeny and evolution of the powdery mildew fungi (*Erysiphales*, *Ascomycota*) inferred from nuclear ribosomal DNA sequences. *Mycoscience*, 45(2), 147-157. <https://doi.org/10.1007/s10267-003-0159-3>

- Takamatsu, S., & Kano, Y. (2001). PCR primers useful for nucleotide sequencing of rDNA of the powdery mildew fungi. *Mycoscience*, 42(1), 135-139.
<https://doi.org/10.1007/BF02463987>
- Takamatsu, S., Braun, U., Limkaisang, S., Kom-Un, S., Sato, Y., & Cunnington, J. H. (2007). Phylogeny and taxonomy of the oak powdery mildew *Erysiphe alphitoides* sensu lato. *Mycological Research*, 111(7), 809-826.
<https://doi.org/10.1016/j.mycres.2007.05.013>
- Takamatsu, S., Havrylenko, M., Wolcan, S. M., Matsuda, S., & Niinomi, S. (2008). Molecular phylogeny and evolution of the genus *Neoerysiphe* (*Erysiphaceae*, *Ascomycota*). *Mycological Research*, 112(6), 639-649.
<https://doi.org/10.1016/j.mycres.2008.01.004>
- Takamatsu, S., Hirata, T., Sato, Y., & Nomura, Y. (1999). Phylogenetic relationships of *Microsphaera* and *Erysiphe* section *Erysiphe* (powdery mildews) inferred from the rDNA ITS sequences. *Mycoscience*, 40(3), 259-268.
<https://doi.org/10.1007/BF02463963>
- Vasyagina, M. P., Kuznetsova, M. N., Pisareva, N. F., & Shvartsman, S. R. (1961). *Flora of spore plants of Kazakhstan. Vol. 3: Powdery mildew fungi*. Alma-Ata, publishing house of the academy of sciences of the KazSSR, pp: 460.
- Wagh, S. H., Kanade, M. B., Thite, S. V., Braun, U., Correia, K. C., Mora-Romero, G. A., & Tovar-Pedraza, J. M. (2022). Powdery mildew on *Coccinia grandis* caused by *Golovinomyces tabaci* in India. *Australasian Plant Disease Notes*, 17(1), 33.
<https://doi.org/10.1007/s13314-022-00480-0>

Appendix

The following abbreviations are used for the gorges: **A** – Ayusai, **BA** – Big Almaty, **B** – Butakov, **I** – Issyk, **Ka** – Kaskelen, **Ku**–Kuznezov, **SA**–Small Almaty, **M**–Monk, **OK** – Oi-Karagai, **P** – Prokhodnoye, **Ta** – Talgar, **TB** – Ters-Butak, **Tu** – Turgen, **UzK** – Uzyn-Kargaly, **Ch** – Chemolgan, **UsK** – Ush-Konyr, **ZhB** – Zhetyzhol ridge, Besmoinak gorge, **ZhA** – Zhetyzhol ridge, Akterek gorge, **KKar** – Kastek ridge, Karakastek gorge, **KKas** – Kastek ridge, Kastek gorge, * – species recorded for the first time as host for Ile-Alatau, ** – new host plant species due to taxonomic revisions, × – treated as new species of powdery mildew fungi due to taxonomic revisions of previously known species.

An annotated checklist of powdery mildew fungi (*Erysiphaceae*) in the Ile-Alatau Mountains (within Kazakhstan)

Order Helotiales Nannf.

Family *Erysiphaceae* Tul. & C. Tul.

- ×**Blumeria bulbiger**a (Bonord.) M. Liu & U. Braun on *Bromus japonicus* Houtt.
Chilik gorge, near the forester's hut, 10.07.1948, S.R. Shvartzman;
on *Bromus inermis* Leyss. (*Bromopsis inermis* (Leyss.) Holub)
up the river Karaturuk, scree, 10.07.1948, S.R. Shvartzman;
on *Bromus racemosus* L.
Kastek ridge, floodplain, 22.06.1955, Z.M. Byzova;
on *Bromus tectorum* L. (*Anisantha tectorum* (L.) Nevski)
up the river Karaturuk, scree, 10.07.1948, S.R. Shvartzman;
on *Bromus* sp.
Ka, on the slope, 07.07.2010, Y.V. Rakhimova; *ibid.*, 10.06.2011, Y.V. Rakhimova; **UzK**, above the dam, 07.07.2010, B.D. Yermekova; **I**, near the lake, 23.06.2011, Y.V. Rakhimova; **ZhB**, 06.07.2016, Y.V. Rakhimova.

- ×**Blumeria dactylidis** M. Liu & Hambl.
on *Dactylis glomerata* L.
SA, 15.07.1957, S.R. Shvartzman; *ibid.*, trail on Kok-Dzhailyau pass, along the Battery river, birch forest, 19.08.2019, U.K. Jetigenova; **A**, spruce forest, 27.08.2018, Y.V. Rakhimova; **P**, spruce forest, 27.07.2012, Y.V. Rakhimova; **Tu**, at the confluence of the tributary with the Bear waterfall, 27.07.2017, Y.V. Rakhimova;
on *Lolium giganteum* (L.) Darbysh. (*Festuca gigantea* (L.) Vill.)
Ta, 28.08.1938, M.N. Kuznezova.

- ×**Blumeria graminicola** M. Liu & Hambl.
on **Calamagrostis arundinacea* (L.) Roth
Tu, trail on Bear waterfall, 22.05.2019, A.M. Assylbek;
on **Milium effusum* L.
nature park “Medeo”, a ridge between the river Small Almaty and Butakov, small gorge, northern slope, 26.05.2020, Y.V. Rakhimova; *ibid.*, western slope, small gorge, deciduous forest, 28.07.2020, Y.V. Rakhimova;
on *Poa angustifolia* L.
UzK, above the dam, 07.07.2010, Y.V. Rakhimova;
on *Poa bulbosa* L.
mountain counters, 05.08.1937, M.N. Kuznezova; **Tu**, 13.07.1956, B.K. Kalymbetov;
on *Poa nemoralis* L.
BA, spruce forest, 04.09.2018, L.A. Kyzmetova; *ibid.*, 31.08.2018, L.A. Kyzmetova, *ibid.*, 04.09.2018, L.A. Kyzmetova; *ibid.*, spruce forests near Big Almaty lake, 07.08.2008, Y.V. Rakhimova; **A**, spruce forest, 28.08.2018, A.M. Assylbek; **Tu**, west of the Assy plateau, 02.08.2016, Y.V. Rakhimova; *ibid.*, trail on Kairak waterfall, 13.07.2019, L.A. Kyzmetova; **P**, spruce forest, 14.07.2019, U.K. Jetigenova, *ibid.*, 14.07.2019, A.M.

Assylbek; **B**, right tributary of the Butakov river, coniferous forest, 07.09.2020, Y.V. Rakhimova;
on *Poa pratensis* L.

SA, spruce forest, 19.07.1948, M.N. Kuznezova;
on *Poa* sp.

P, upper border of spruce forests, 27.07.2012, Y.V. Rakhimova.

Note: The species is widely distributed on the territory of the Trans-Ili Alatau.

Blumeria graminis (DC.) Speer

on *Aegilops cylindrica* Host

Ka, Kasymbek ravine, 03.06.2015, Y.V. Rakhimova;
on *Aegilops* sp.,

Deep canyon, south slope, at the bottom of the hill, 11.06.1946, M.N. Kuznezova;

on *Brachypodium sylvaticum* (Huds.) P. Beauv.

SA, along the Battery River, 23.08.1945, M.N. Kuznezova;

on *Elymus sibiricus* L.

BA, spruce forest, 05.09.2018, Y.V. Rakhimova;

on ****Elymus uralensis** (Nevski) Tzvelev (*E. tianschanigenus* Czerep.)

SA, along the Battery River, 07.10.1945, M.N. Kuznezova.

Erysiphe adunca (Wallr.) Fr.

on *Populus tremula* L.

SA, near the dam, 29.09.1937, M.N. Kuznezova; **BA**, crest of Big Almaty peak, 29.08.2018, L.A. Kyzmetova; **ibid.**, in the floodplain of Big Almaty River, 07.08.2008, Y.V. Rakhimova;

Erysiphe aquilegiae DC.

on *Aconitum septentrionale* Koelle (*A. excelsum* Rchb.)

on aspen forest along the river Kazachka, 28.08.1937, M.N. Kuznezova, northern slope on the way to Talgar pass, rare spruce forests, 26.08.1946, M.N. Kuznezova;

on *Aconitum karakolicum* Rapaics

Small Kemin gorge, Aktyuz, 2300 m a. s. l., 04.09.1957, B.K. Kalymbetov;

on *Aconitum leucostomum* Vorosch.

KKas, 29.06.2012, Y.V. Rakhimova; Nature Park “Medeo”, a ridge between the river Small Almaty and Butakov, small gorge, below the Samal complex, north-western slope, deciduous forest, 14.06.2020, G. Sypabekkyzy;

on *Aconitum rotundifolium* Kar. & Kir.

Small Kemin gorge, Aktyuz, 2300 m a. s. l., 04.09.1957, B.K. Kalymbetov; climbing to Mount Kumbel, near the Three Brothers rocks, 16.08.2012, Y.V. Rakhimova;

on *Aquilegia karelini* (Baker) O. & B. Fedtsch.

I, when going up to the lake Issyk, 19.08.1937, M.N. Kuznezova; **SA**, near Gorelnik, 31.08.1946, S.R. Shvartzman;

on *Aquilegia* sp.

A, spruce forest, 28.08.2018, L.A. Kyzmetova;
on *Clematis sibirica* (L.) Mill. (*Atragene sibirica* L.)

BA, spruce forest, 04.09.2018, L.A. Kyzmetova;
on *Clematis tangutica* (Maxim.) Korsh.

I, 1400 m a. s. l., 12.09.1957, B. K. Kalymbetov;

on *Delphinium iliense* Huth (only anamorph)

SA, 18.08.1948, S.R. Shvartzman, Toadstool gorge, 2000 m a. s. l., 26.07.1956, B.K. Kalymbetov;

on *Delphinium* sp.

Deep canyon, south slope, shrubs, 11.06.1946, M.N. Kuznezova;

on *Ranunculus polyanthemus* L.

SA, Battery river, slope, 07.10.1945, M.N. Kuznezova;
on *Ranunculus* sp.

BA, crest of Big Almaty peak, 29.08.2018, L.A. Kyzmetova; **ibid.**, deciduous forest, 01.07.2020, G.A. Urmanov; **A**, 28.08.2018, A.M. Assylbek; **P**, 14.07.2019, Y.V. Rakhimova; **ibid.**, 15.07.2019, L.A. Kyzmetova;

ibid., spruce forest, 14.07.2019, A.M. Assylbek; **M**, 07.09.2012, Y.V. Rakhimova; **OK**, 20.09.2012, G.A. Nam; **SA**, Mynzhilki tract, 01.08.2015, R.D. Rakhimov;

nature park “Medeo”, **B**, western slope, deciduous forest, 21.08.2020, E.S. Sametova;

on *Thalictrum foetidum* L.

SA, 29.08.1938, M.N. Kuznezova; right bank of the Kiben river, 1600 m a. s. l., 08.09.1957, B. K. Kalymbetov;

on *Thalictrum minus* L.

A, spruce forest, 27.08.2018, L.A. Kyzmetova; **P**, near the waterfall, spruce forest, 14.07.2019, U.K. Jetigenova;

on **Thalictrum simplex* L.

Kimasar gorge, on the way to Furmanov hill on the ridge, 10.09.2020, G.A. Urmanov;

on *Thalictrum* sp.

M, 07.09.2012, Y.V. Rakhimova; **SA**, climbing to Mount Kumbel, 15.08.2012, Y.V. Rakhimova; **BA**, 06.09.2011, Y.V. Rakhimova; **B**, the confluence of the right tributary with the waterfall in the Butakov river, mixed forest, 07.09.2020, A.M. Assylbek; **KKas**, 28.06.2012, B.Y. Dzhunuskanova;

on *Trollius dschungaricus* Regel

ascent to the Talgar pass, 2300 m a. s. l., 25.08.1946, M.N. Kuznezova.

Note: The species is widely distributed on the territory of the Ile-Alatau.

Erysiphe astragali DC.

on *Astragalus alpinus* L.

SA, along the northern slope of Kumbel, 09.10.1937, M.N. Kuznezova; **BA**, spruce forest, 01.09.2018, A.M. Assylbek;

on *Astragalus sewertzowii* Bunge

30.09.1939, M.N. Kuznezova;

on *Astragalus* sp.

BA, 28.07.2008, Y.V. Rakhimova; **B**, in the vicinity of the Upper Butakov waterfall, coniferous forest,

09.09.2020, B.Y. Dzhunuskanova; **KKas**, 28.06.2012, B.Y. Dzhunuskanova;
on *Oxytropis macrocarpa* Kar. & Kir.
Ta, south-eastern slope, 11.07.1956, B.K. Kalymbetov;
on *Oxytropis globiflora* Bunge (*O. pagobia* Bunge)
30.07.1947, M.N. Kuznezova.
Note: The species is not often found on the territory of the Ile-Alatau.

Erysiphe atraphaxis (Golovin) U. Braun & S. Takam.
on *Atraphaxis frutescens* (L.) Eversm.
Ch, eastern slope, 23.08.1958, B.K. Kalymbetov;
on *Atraphaxis muschketowii* Krasn.
Aksai gorge, 09.09.1937, M.N. Kuznezova; Deep canyon, 10.10.1945, M.N. Kuznezova;
on *Atraphaxis* sp.
ZhA, 27.06.2014, U.K. Jetigenova;
Note: The species *Erysiphe atraphaxis*, as well as its host (representatives of the genus *Atraphaxis*) are confined to the low mountains of the Ile-Alatau and are not often found.

×*Erysiphe baeumleri* (Magnus) U. Braun & S. Takam.
(= *E. pisi* DC.)
on *Vicia* sp.
Chilik gorge, 10.07.1948, S.R. Shvartzman; **M**, 07.09.2012, Y.V. Rakhimova; *ibid.*, 15.08.2013, Y.V. Rakhimova; **OK**, 20.09.2012, G.A. Nam.
Note: The species is rare in the Ile-Alatau.

Erysiphe berberidis DC.
on *Berberis heteropoda* Schrenk (*B. sphaerocarpa* Kar. & Kir.)
SA, south slope, 13.08.1945, M.N. Kuznezova, **B**, 28.08.2020, Y.V. Rakhimova; **I**, 1700 m a. s. l., 12.09.1957, B. K. Kalymbetov; **BA**, crest of Big Almaty peak, 29.08.2018, L. A. Kyzmetova; **A**, spruce forest, 27.08.2018, Y.V. Rakhimova; **TB**, 16.08.2012, Y.V. Rakhimova; **KKar**, 03.08.2016, Y.V. Rakhimova; **OK**, 20.09.2012, G.A. Nam;
on *Berberis* sp.
SA, 21.10.1938, M.N. Kuznezova, *ibid.*, 14.08.1948, I.N. Golovenko; **BA**, in the floodplain, 06.09.2011, Y.V. Rakhimova.
Note: The species is widely distributed on the territory of the Ile-Alatau.

Erysiphe betae (Vanha) Weltzien
on *Beta vulgaris* L. (Fig. 1A)
24.09.1957, B. K. Kalymbetov; *ibid.*, Kyrgauldy, 17.09.2019, Y.V. Rakhimova.
Note: The species is rare in the Ile-Alatau.



Fig. 1A: *Erysiphe betae* on *Beta vulgaris* leaves

×*Erysiphe caprea* DC. ex Duby
on *Salix cinerea* L.
B, 1500 m a. s. l., 23.10.1937, M.N. Kuznezova.
on *Salix* sp.
Ch, in the floodplain of Chemolgan river, 12.09.2010, Y.V. Rakhimova.
Note: The *E. adunca* complex has been divided into several species, including *E. capreae* (Darsaraei *et al.*, 2021).

Erysiphe celtidis (Schwarzman & Kuznezowa) U. Braun & S. Takam.
on *Celtis caucasica* Willd.
SA, Butakov canyon, 1500 m a. s. l., 20.10.1946, M.N. Kuznezova; *ibid.*, 30.10.1948, S.R. Shvartzman; *ibid.*, 26.10.1958, V.A. Kostin.
Note: The species is rare in the Ile-Alatau.

Erysiphe convolvuli DC.
on *Convolvulus arvensis* L.
SA, 16.07.1945, M.N. Kuznezova.
Note: The species is rare in the Ile-Alatau.

Erysiphe cruchetiana S. Blumer
on *Lathyrus gmelinii* Fritsch, *L. pratensis* L.
I, 1600 m a. s. l., 12.09.1957, B.K. Kalymbetov; nature park “Medeo”, **B**, western slope, deciduous forest, 21.08.2020, G.A. Urmanov;
on *Lathyrus pisiformis* L.
Ku, southeast slope, 15.08.2013, Y.V. Rakhimova;
on *Lathyrus tuberosus* L.
Chilik gorge, 10.08.1948, S.R. Shvartzman;
on *Lathyrus* sp.
M, 07.09.2012, Y.V. Rakhimova.
Note: The species is quite widespread in the Ile-Alatau.

Erysiphe cruciferarum (Opiz) L. Junell
on **Alyssum dasycarpum* Stephan ex Willd.
ZhB, 06.07.2016, Y.V. Rakhimova;
on **Alyssum szovitsianum* Fisch. & C.A. Mey. (*A. marginatum* Steud. ex Boiss.)

Ka, 10.06.2011, Y.V. Rakhimova;
on *Alyssum desertorum* Stapf (*A. turkestanicum* var.
desertorum (Stapf) Botsch)

Kara-Turuk canyon, 08.07.1948, S.R. Shvartzman;
Ch, 30.08.1957, S.R. Shvartzman;
on *Berteroa incana* (L.) DC.
bank of the Small Almaty River, 18.09.1937, M.N.
Kuznezova; **Ta**, 23.06.2011, Y.V. Rakhimova; **Tu**, on the
way to Bear waterfall, 12.07.2019, L.A. Kyzmetova;
on *Camelina microcarpa* Andr. (*C. sylvestris*
(Maxim.) Korsh.)

ZhB, 06.07.2016, Y.V. Rakhimova; **SA**, 27.06.1946,
S.R. Shvartzman;
on *Capsella bursa-pastoris* (L.) Medikus

SA, 30.08.1946, M.N. Kuznezova;
on *Catolobus pendula* (L.) Al-Shehbaz (*Arabis*
pendula L.)
right bank of the Assy river, 05.08.2012, Y.V.
Rakhimova;

on *Erysimum diffusum* Ehrh.
Small Kemin gorge, Aktjuz, 2400 m a. s. l.,
06.09.1957, B. K. Kalymbetov;

on *Hesperis matronalis* L.
SA, bank of the Battery River, shrubs, 17.09.1938,
M.N. Kuznezova;

on *Pseudoclausia turkestanica* (Lipsky) A.N.
Vassiljeva (*Parrya khorasanica* (Rech. f. & Aellen) D.A.
German & Al-Shehbaz)

BA, 2300 m a. s. l., 12.06.1958, B.K. Kalymbetov;
on *Sisymbrium* sp.
Deep canyon, 10.10.1945, M.N. Kuznezova;
on *Thlaspi arvense* L.

ZhB, 06.07.2016, Y.V. Rakhimova.

Note: The species is widely distributed on the territory
of the Ile-Alatau.

Erysiphe diffusa (Cooke & Peck) U. Braun & S.
Takam.

on *Glycyrrhiza glabra* L.

SA, 1938, M.N. Kuznezova.

Note: The species is rare in the Ile-Alatau.

Erysiphe ehrenbergii (Lév.) U. Braun, M. Bradshaw
& S. Takam.

on *Lonicera altmannii* Regel & Schmalh.

SA, at the foot of the Shaggy hill, 08.09.1938, M.N.
Kuznezova;

on *Lonicera caerulea* subsp. *stenantha* (Pojark.)
Hultén ex A. K. Skvortsov (*L. stenantha* Pojark.)

SA, 07.09.1937, M.N. Kuznezova.

on *Lonicera* sp. (only anamorph)

BA, 2550 m a. s. l., 20.08.2008, Y.V. Rakhimova.

Note: The species is rare in the Ile-Alatau.

Erysiphe friesii (Lév.) U. Braun & S. Takam.

on *Rhamnus cathartica* L.

Ch, in the floodplain of Chemolgan river, 12.09.2010,
Y.V. Rakhimova; **Ku**, 15.08.2013, Y.V. Rakhimova.

Note: The species is rare in the Ile-Alatau.

Erysiphe geraniacearum U. Braun & Simonyan
on *Geranium collinum* Stephan ex Willd.

SA, 16.08.1957, B. K. Kalymbetov,
on *Geranium pratense* L.

Kara-Turuk gorge, 31.07.1947, S.R. Shvartzman.

Note: The species is rare in the Ile-Alatau.

Erysiphe heraclei DC. on *Aegopodium alpestre* Ledeb.
on the way to Yunnat Lake, 31.08.1954, A. Y. Baigulova;
on **Anthriscus sylvestris* (L.) Hoffm.

SA, on the way to Kok-Dzhailau pass, pine forest,
19.08.2019, G. Sypabekkyzy; nature park “Medeo”, a
ridge between the river Small Almaty and Butakov,
western slope, small anyone, deciduous forest,
28.07.2020, Y.V. Rakhimova;

on *Conioselinum tataricum* Hoffm. (*C. latifolium* Rupr.)

SA, bank of the Battery River, aspen forests,
30.09.1948, S.R. Shvartzman; **UzK**, 07.07. 2010. Y.V.
Rakhimova;

on *Daucus carota* L.

SA, 18.09.1938, M.N. Kuznezova;

on *Daucus carota* subsp. *sativus* (Hoffm.) Schübl. &
Martens

Ch, 28.09.1959, M.P. Vassyagina; foothills, in the
vicinity of the village of Tausamal, 26.07.2018, Y.V.
Rakhimova.

on *Eryngium macrocalyx* Schrenk

SA, bank of the Battery River, 07.10.1945, M.N.
Kuznezova;

on *Ferula tatarica* Fisch. ex. Spreng.

surrounding area of the village Sagakurus, 04.08.1956,
M.P. Vassyagina;

on *Heracleum dissectum* Ledeb.

SA, aspen forests, 07.10.1938, M.N. Kuznezova;

on *Heracleum* sp.,

nature park “Medeo”, a ridge between the river Small
Almaty and Butakov, western slope, small anyone,
deciduous forest, 28.07.2020, Y.V. Rakhimova.

on *Seseli libanotis* (L.) W.D.J. Koch

SA, 17.10.1937, M.N. Kuznezova;

on *Seseli schrenkianum* (C.A. Mey. ex Schischk.)
Pimenov & Sdobnina

Ka, 03.08.2016, Y.V. Rakhimova; **KKar**, 03.08.2016,
Y.V. Rakhimova;

on *Seseli* sp.

between Maitobe and Araltobe mountains, Ulkensaz,
2500 m a. s. l., 01.09.1957, B.K. Kalymbetov; **Ch**, eastern
slope, 1300 m a. s. l., 01.09.1957, B.K. Kalymbetov;

on *Turgenia latifolia* (L.) Hoffm.

foothills, Deep canyon, north-western slope,
13.07.1945, M.N. Kuznezova.

Note: The species is widely distributed on the territory
of the Ile-Alatau.

Erysiphe hedysari (U. Braun) U. Braun & S. Takam.
on *Hedysarum songoricum* Bong. (*H. montanum* (B.
Fedtsch.) B. Fedtsch.)

Deep canyon, south slope, 20.07.1946, M.N.
Kuznezova;

Note: The species is rare in the Ile-Alatau.

Erysiphe hyperici (Wallr.) S. Blumer
on *Hypericum hirsutum* L.

SA, 19.10.1937, M.N. Kuznezova; nature park
“Medeo”, a ridge between the river Small Almaty and
Butakov, western slope, small canyon, deciduous forest,
28.07.2020, G.A. Urmanov; **B**, in the vicinity of the Upper
Butakovsky waterfall, coniferous forest, 09.09.2020, B.Y.
Dzhunuskanova; **I**, 1600 m a. s. l., 12.09.1957, B.K.
Kalymbetov; **BA**, crest of Big Almaty peak, birch forest,
29.08.2018, U.K. Jetigenova; **M**, 07.09.2012, Y.V.
Rakhimova; **KKar**, 03.08.2016, Y.V. Rakhimova; **Ka**,
surroundings of the village of Izvestkovoe, 19.09.2013,
Y.V. Rakhimova;

on *Hypericum perforatum* L.

Ka, surroundings of the village of Izvestkovoe,
19.09.2012, Y.V. Rakhimova.

Note: The species is quite widespread in the Ile-Alatau.

Erysiphe hypophylla (Nevod.) U. Braun & Cunningt.
on *Quercus robur* L.

SA, 10.08.1948, S.R. Shvartzman, forestry enterprises
of Kaskelen and Chilik districts, 1950–1952, V.K.
Matveyeva; nature park “Medeo”, a ridge between the
river Small Almaty and Butakov, small gorge, northeast
slope, 23.06.2020, G. Sypabekkyzy.

Note: The species is quite widespread in the Ile-
Alatau. The chasmothecia of *E. hypophylla* are
morphologically very similar to those of *E. alphitoides*,
but these species are easily distinguishable by their
symptoms, as well as the shape and size of the conidia
(Takamatsu *et al.*, 2007).

Erysiphe limonii L. Junell (= *E. stactices* (Potebnia)
V.P. Heluta, Tikhon., Burgyuk. & Dudka)

on *Limonium gmelinii* (Willd.) Kuntze
foothill plain, salt marshes, surrounding area of the
village Lavar, 24.09.1957, B.K. Kalymbetov.

Note: The species is rare in the Ile-Alatau.

×*Erysiphe mayorii* S. Blumer
on *Cicerbita azurea* (Ledeb.) Beauverd

A, eastern slope, spruce forest, 27.08.2018, U.K.
Jetigenova; *ibid.*, southeast slope, 27.08.2018, L.A.
Kyzmetova; **P**, spruce forest, 14.07.2019, A.M. Assylbek; **B**,
the confluence of the right tributary with the waterfall in the
Butakov river, mixed forest, 07.09.2020, A.M. Assylbek;

on *Cicerbita* sp.

P, spruce forest, 27.07.2012, Y.V. Rakhimova; *ibid.*,
14.07.2019, A.M. Assylbek; **M**, 07.09.2012, Y.V.
Rakhimova;

Note: The species is quite widespread in the Ile-Alatau.

Erysiphe ornata (U. Braun) U. Braun & S. Takam.
on *Betula pendula* Roth

BA, birch forest, 29.08.2018, L.A. Kyzmetova;
on *Betula pendula* subsp. *pendula* (*B. verrucosa* Ehrh.)
I, 1400 m a. s. l., 12.09.1957, B.K. Kalymbetov;
on *Betula tianschanica* Rupr.

SA, 18.09.1937, M.N. Kuznezova;
on *Betula* sp.

SA, southern slope, 15.10.1945, M.N. Kuznezova.

Note: The species is rare in the Ile-Alatau.

Erysiphe polygoni DC.

on *Polygonum arenarium* Waldst. & Kit.

OK, 20.09.2012, G.A. Nam;

on *Polygonum aviculare* L.

Ch, 1900 m a. s. l., 30.08.1957, B.K. Kalymbetov;
KKar, 28.06.2012, Y.V. Rakhimova; nature park
“Medeo”, a ridge between the river Small Almaty and
Butakov, small gorge, below the Samal complex,
northwest slope, deciduous forest, 14.06.2020, Y.V.
Rakhimova;

on *Rumex acetosa* L.

BA, mixed forest, 29.08.2018, Y.V. Rakhimova;

on *Rumex crispus* L.

I, foothills, 18.08.1937, M.N. Kuznezova; **SA**, on the
way to the Kok-Dzhailau, 16.08.2012, Y.V. Rakhimova;
BA, ascent to the lake, 20.08.2008, Y.V. Rakhimova; **Ka**,
surroundings of the village of Izvestkovoe, 19.09.2012,
Y.V. Rakhimova;

on *Rumex confertus* Willd.

KKar, 03.08.2016, Y.V. Rakhimova;

on *Rumex tianschanicus* Losinsk.

I, 12.09.1957, B.K. Kalymbetov; **BA**, crest of Big
Almaty peak, deciduous forest, 01.07.2020, Y.V.
Rakhimova; nature park “Medeo”, a ridge between the
river Small Almaty and Butakov, small gorge, western
slope, deciduous forest, 28.07.2020, G.A. Urmanov; **B**, in
the vicinity of the Upper Butakovsky waterfall, coniferous
forest, 09.09.2020, B.Y. Dzhunuskanova;

on *Rumex* sp.



Fig. 2A: *Erysiphe sophorae* on *Sophora alopecuroides* peduncles

BA, crest of Big Almaty peak, mixed forest, 29.08.2018, Y.V. Rakhimova; *ibid.*, ascent to the lake, 13.08. 2009, Y.V. Rakhimova; **Tu**, Assy, 05.08.2012, Y.V. Rakhimova; **UzK**, above the dam, 07.07.2010, B.D. Yermekova; **KKas**, 17.09.2011, Y.V. Rakhimova; **UsK**, 11.07. 2010, Y.V. Rakhimova; **Ta**, 23.06.2011, Y.V. Rakhimova; **Ka**, surroundings of the village of Izvestkovoe, 19.09.2012, Y.V. Rakhimova; **SA**, Mynzhilki, 01.08.2015, R.D. Rakhimov; *ibid.*, on the way to the Kok-Dzhailau, 19.08.2019, A.M. Assylbek; **P**, floodplain of the river, 16.07.2019, L.A. Kyzmetova.

Note: The species is widely distributed on the territory of the Ile-Alatau.

Erysiphe sophorae (Jacq.) U. Braun

on *Sophora alopecuroides* L. (*Pseudosophora alopecuroides* (L.) Sweet) (Fig. 2A-3A)

Deep canyon, 14.09.1938, M.N. Kuznezova; Aksai gorge, 29.08.1939, M.N. Kuznezova.

Note: The species is rare in the Ile-Alatau.

Erysiphe thesii L. Junell

on *Thesium alatavicum* Kar. & Kir.

BA, 12.09.1959, S.R. Shvartzman; *ibid.*, below the peak of the Young geologist, the border of spruce forests, 18.07.2012, Y.V. Rakhimova; *ibid.*, southwestern slope, spruce forest, 03.09.2018, U.K. Jetigenova, *ibid.*, western slope, 05.09.2018, A.M. Assylbek; *ibid.*, spruce forests near the Big Almaty Lake, 28.07.2008, Y.V. Rakhimova.

Note: The species is quite widespread in the Ile-Alatau.

Erysiphe thuenenii U. Braun

on *Potentilla* sp.

Chilik gorge, 10.07.1948, S.R. Shvartzman.

Note: The species is rare in the Ile-Alatau.

Erysiphe trifoliorum (Wallr.) U. Braun

Erysiphe urticae (Wallr.) S. Blumer

on *Urtica dioica* L.

SA, aspen forests, 07.10.1938, M.N. Kuznezova; nature park “Medeo”, B, western slope, deciduous forest, 21.08.2020, G.A. Urmanov; **M**, 07.09.2012, Y.V. Rakhimova; **UzK**, above the dam, 07.07.2010. Y.V. Rakhimova;



Fig. 3A: *Erysiphe sophorae* on *Sophora alopecuroides* leaves

on *Urtica cannabina* L.

SA, 25.08.1957, B.K. Kalymbetov; foothill, village Lavar, 24.09.1957, B.K. Kalymbetov; **KKas**, 17.09.2011, Y.V. Rakhimova.

Note: The species is quite widespread in the Ile-Alatau.

Golovinomyces adenophorae (R.Y. Zheng & G.Q. Chen) V.P. Heluta.

on *Adenophora liliifolia* (L.) A. DC.

I, 16.04.1938, I. Ryabov.

Note: The species is rare in the Ile-Alatau.

Golovinomyces artemisiae (Grev.) V.P. Heluta

on *Artemisia absinthium* L.

A, eastern slope, spruce forest, 28.08.2018, L.A. Kyzmetova;

on *Artemisia dracunculus* L.

SA, 05.10.1938, M.N. Kuznezova; **Ch**, 1300 m a. s. l., 29.08.1957, B.K. Kalymbetov; **BA**, in the floodplain, 06.09.2011. Y.V. Rakhimova; **Ku**, southeast slope, 15.08.2013, Y.V. Rakhimova;

on *Artemisia vulgaris* L.

BA, crest of Big Almaty peak, mixed forest, 29.08.2018, Y.V. Rakhimova; *ibid.*, 06.09.2011, Y.V. Rakhimova; **M**, 07.09.2012, Y.V. Rakhimova; **Ka**, surroundings of the village of Izvestkovoe, 19.09.2012, Y.V. Rakhimova; nature park “Medeo”, **B**, western slope, deciduous forest, 21.08.2020, E.C. Sametova;

on *Artemisia* sp.

Small Kemin gorge, 2500 m a. s. l., 06.09.1957, B.K. Kalymbetov; **Tu**, Assy, 05.08.2012, Y.V. Rakhimova; **OK**, 20.09.2012, G.A. Nam.

Note: The species is widely distributed on the territory of the Ile-Alatau.

Golovinomyces asterum (Schwein.) U. Braun

on *Aster alpinus* L.

BA, northwestern slope, spruce forest, 01.09.2018, A.M. Assylbek, *ibid.*, northern slope, spruce forest, 10.09.2018, Y.V. Rakhimova;

on *Galatella punctata* (Waldst. & Kit.) Nees

floodplain of the Kaskelen river, 29.09.1939, M.N. Kuznezova; **SA**, 20.09.1954, B.K. Kalymbetov;

on *Galatella* sp.

SA, Lebedev canyon, 22.09.1954, S.R. Shvartzman.

on *Solidago virgaurea* L.

SA, spruce forest, 30.04.1939, M.N. Kuznezova; **B**, the confluence of the right tributary with the waterfall in the Butakov river, mixed forest, 07.09.2020, A.M. Assylbek.

Note: The species is quite widespread in the Ile-Alatau. According to modern research (Mieslerová *et al.*, 2020) the species *Golovinomyces asterum* forms the three varieties: var. *asterum*, var. *morozkovskii*, var. *solidaginis*.

Golovinomyces biocellatus (Ehrenb.) V.P. Heluta

on ****Eriophyton lamiiflorum** (Rupr.) Bräuchler (*Stachyopsis lamiiflora* (Rupr.) Popov & Vved.)

SA, 21.07.1945, M.N. Kuznezova; **Ch**, 1700 m a. s. l., 30.08.1957, B.K. Kalymbetov; **OK**, 20.09.2012, G.A. Nam; on ****Eriophyton oblongatum** (Schrenk) Bendiksbj (Stachyopsis oblongata (Schrenk ex Fisch. & C.A. Mey.) Popov & Vved.)

BA, 20.08.1937, M.N. Kuznezova; **I**, forest above the lake Issyk, 14.07.2015, Y.V. Rakhimova; **Ka**, surroundings of the village of Izvestkovoe, 19.09.2012, Y.V. Rakhimova;

on ****Eriophyton** sp. (*Stachyopsis* sp.)

KKas, 17.09.2011, Y.V. Rakhimova; **M**, 07.09.2012, Y.V. Rakhimova;

on *Lycopus europaeus* L.

Ka, floodplain, 09.08.1939, B.K. Kalymbetov;

on *Stachys sylvatica* L.

SA, 07.09.1946, M.N. Kuznezova; **A**, southeast slope, spruce forest, 27.08.2018, L.A. Kyzmetova; **TB**, 16.08.2012, Y.V. Rakhimova; nature park “Medeo”, gorge Butakov, western slope, deciduous forest, 21.08.2020, E.C. Sametova; *ibid.*, a ridge between the river Small Almaty and Butakov, small canyon below the Samal complex, northwest slope, deciduous forest, 14.06.2020, G. Sypabekkyzy;

on *Ziziphora clinopodioides* Lam.

KKas, 17.09.2011, Y.V. Rakhimova;

on *Ziziphora tenuior* L.

low mountains, 25.07.1946, M.N. Kuznezova.

Note: The species is widely distributed on the territory of the Ile-Alatau. Using asexual state morphology and rDNA sequence data Scholler *et al.* (2016) propose to consider within the complex species

Golovinomyces biocellatus four co-related species – *G. monardae*, *G. biocellatus*, *G. salviae* u *G. neosalviae* sp. nov. Revision of samples from Central Asia and Kazakhstan is necessary.

Golovinomyces cichoracearum (DC.) V.P. Heluta

on *Cichorium intybus* L.

Ta, 23.06.2011, Y.V. Rakhimova;

on *Crepis sibirica* L.

SA, inside the spruce forest, 16.08.1957, B.K. Kalymbetov;

on *Crepis* sp.

SA, 1937, M.N. Kuznezova;

on *Hieracium virosum* Pall.

SA, Butakov canyon, aspen forests, 24.10.1937, M.N. Kuznezova; **Ch**, 1350 m a. s. l., 23.08.1958, B.K. Kalymbetov; **BA**, southwestern slope, spruce forest, 03.09.2018, A.M. Assylbek; *ibid.*, near the road to the lake, 20.08.2008, Y.V. Rakhimova; **B**, in the vicinity of the Upper Butakov waterfall, coniferous forest, 09.09.2020, B.E. Dzhunuskanova;

on *Hieracium* sp.

I, forest above the Issyk lake, 14.07.2015, Y.V. Rakhimova; **M**, 07.09.2012, Y.V. Rakhimova;

on ****Lactuca tianschanica** (Regel & Schmalh.) (*Cicerbita tianschanica* (Regel & Schmalh.) Beauverd, *Mulgedium tianschanicum* Regel & Schmalh.)

SA, bank of the Kazachka river, aspen forests, 11.09.1937, M.N. Kuznezova;

on *Tragopogon capitatus* Nikitin

Tu, trail on Bear falls, 12.07.2019, L.A. Kyzmetova.

Note: The complex species is widely distributed on the territory of the Ile-Alatau.

Golovinomyces cynoglossi (Wallr.) V.P. Heluta s. l.

on *Arnebia tschimganica* (B. Fedtsch.) G. L. Chu (*Ulugbekia tschimganica* (B. Fedtsch.) Zakirov)

SA, in the area of forestry, 23.06.1956, B.K. Kalymbetov.

on *Asperugo procumbens* L.

BA, near **A**, 14.07.2011, Y.V. Rakhimova;

on *Buglossoides arvensis* (L.) I.M. Johnst.

ZhB, 06.07.2016, Y.V. Rakhimova;

on *Cynoglossum circinnatum* (Ledeb.) Greuter & Burdet (*Solenanthus circinnatus* Ledeb.)

foothills, apple forests, 25.06.1941, M.N. Kuznezova;

on *Cynoglossum officinale* L.

A, spruce forest, 27.08.2018, U.K. Jetigenova;

on *Echium vulgare* L.

SA, 18.10.1937, M.N. Kuznezova; **I**, 1300 m a. s. l., 13.09.1957, B.K. Kalymbetov; **Tu**, 15.08.2013, Y.V. Rakhimova; *ibid.*, trail on Bear falls, 12.07.2019, L.A. Kyzmetova; nature park “Medeo”, a ridge between the river Small Almaty and Butakov, western slope, small canyon, deciduous forest, 28.07.2020, Y.V. Rakhimova;

on *Echium* sp.

BA, near **A**, 14.07.2011, Y.V. Rakhimova;

on *Lappula microcarpa* (Ledeb.) Gurke

Ch, 1200 m a. s. l., 01.06.1958, B.K. Kalymbetov on *Lappula* sp.

BA, crest of Big Almaty peak, 29.08.2018, Y.V. Rakhimova;

on *Lithospermum officinale* L.

UzK, above the dam, 07.07.2011, Y.V. Rakhimova; nature park “Medeo”, a ridge between the river Small Almaty and Butakov, western slope, small canyon, deciduous forest, 28.07.2020, G.A. Urmanov;

on *Myosotis alpestris* F.W. Schmidt

P, border of pine and birch forests, 14.07.2019, Y.V. Rakhimova.

Note: The species is widely distributed on the territory of the Ile-Alatau. Phylogenetic analysis of rDNA ITS sequences of specimens (Braun *et al.*, 2018) revealed that *G. cynoglossi* s. lat. involved several species in five clearly separated lineages: On *Cynoglossum*, on *Symphytum* and *Pulmonaria*, on *Bothriospermum*, *Buglossoides*, *Echium*, *Myosotis*, and *Trigonotis*. Some taxa are now assigned to *G. asperifoliorum* comb. nov. and to *G. asperifolii* comb. nov. Further molecular

phylogenetic studies of *Golovinomyces* species (Fig. 4A) on Boraginaceae in Kazakhstan would be necessary for resolving this complex, which may contain still unknown *Golovinomyces* species (Braun *et al.*, 2018).

Golovinomyces depressus (Wallr.) V.P. Heluta

on *Arctium lappa* L.

I, 1400 m a. s. l., 14.09.1957, B.K. Kalymbetov;

on *Arctium tomentosum* Mill.

SA, northern slope, 20.08.1937, M.N. Kuznezova; *ibid.*, on the way to the Kok-Dzhailau pass, 15.08.2012, Y.V. Rakhimova; **BA**, crest of Big Almaty peak, 29.08.2018, Y.V. Rakhimova; **OK**, 20.09.2012, G.A. Nam; nature park “Medeo”, a ridge between the river Small Almaty and Butakov, small gorge, below the Samal complex, northwest slope, deciduous forest, 14.06.2020, Y.V. Rakhimova; *ibid.*, western slope, small canyone, deciduous forest, 28.07.2020, G.A. Urmanov;

on *Arctium* sp.

OK, 20.09.2012, G.A. Nam; Kimasar gorge, on the way to Furmanov hill on the ridge, 10.09.2020, G.A. Urmanov;

on *Onopordum acanthium* L.

foothills, Deep canyon, 14.09.1938, M.N. Kuznezova; on *Onopordum* sp.

SA, bank of the Battery River, 30.09.1939, M.N. Kuznezova; **KKas**, 29.06.2012, Y.V. Rakhimova.

Note: The species is quite widespread in the Ile-Alatau.

Golovinomyces hyoscyami (R. Y. Zheng & G. Q. Chen) V. P. Heluta

on *Hyoscyamus niger* L. (only anamorph) (Fig. 5A)

foothills, bank of the Aksai River, 15.08.1939, M.N. Kuznezova; **I**, in the vicinity of the lake, deciduous forest, 1631 m a. s. l., 19.08.2021, Y.V. Rakhimova.

Note: The species is rare in the Ile-Alatau.



Fig. 4A: *Golovinomyces magnicellulatus* on *Polemonium caeruleum*



Fig. 5A: *Golovinomyces hyoscyami* on *Hyoscyamus niger*

Golovinomyces inulae U. Braun & H.D. Shin

on *Inula britannica* L.

floodplain Kaskelen river, 09.09.1939, M.N. Kuznezova; on *Inula helenium* L.

BA, crest of Big Almaty peak, mixed forest, 29.08.2018, A.M. Assylbek; *ibid.*, on the way to the Big Almaty Lake, 20.08.2008, Y.V. Rakhimova; *ibid.*, floodplain forest, 08.08.2011, Y.V. Rakhimova; **SA**, Lebedev canyon, 22.09.1954, N.M. Filimonova; *ibid.*, on the way to the Kok-Dzhailau pass, 15.08.2012, Y. V. Rakhimova; nature park “Medeo”, **B**, western slope, deciduous forest, 21.08.2020, G. A. Urmanov; **Ku**, 15.08.2013, Y. V. Rakhimova; **P**, 16.07.2019, L. A. Kyzmetova.

Note: The species is quite widespread in the Ile-Alatau.

Golovinomyces montagnei U. Braun,

on *Carduus nutans* L.

SA, bank of the Battery River, 30.09.1939, M. N. Kuznezova;

on *Cirsium arvense* (L.) Scop.

foothill plain, Lavar village, 24.09.1957, B. K. Kalymbetov;

on *Cousinia* sp.

M, under the rock, 24.08.1935, G.S. Nevodovsky;

on *Crupina vulgaris* (Pers.) Cass.

SA, 08.08.1946, M.N. Kuznezova;

on ****Stizolophus balsamita** (Lam.) Cass. (*Centaurea balsamita* Lam.)

I, 1500 m a. s. l., 14.09.1957, B.K. Kalymbetov; **Ch**, 1700 m a. s. l., 30.08.1957, B.K. Kalymbetov.

Note: The species is rare in the Ile-Alatau.

Golovinomyces sordidus (L. Junell) V.P. Heluta

on *Plantago maritima* L.

BA, 15.08.1939, M.N. Kuznezova.

Note: The species is rare in the Ile-Alatau.

×*Golovinomyces tabaci* (Sawada) H.D. Shin, S. Takam. & L. Kiss (= *G. orontii* (Castagne) V.P. Heluta) on *Citrullus lanatus* (Thunb.) Matsum. & Nakai (*Citrullus vulgaris* Schrad.)

BA, 24.09.1937, G.S. Nevodovsky.

on *Papaver somniferum* L.

foothills, 20.08.1937, L.D. Kazenas.

Note: The species is rare in the Ile-Alatau. There is a number of *Golovinomyces* species with similar morphology known to infest cucurbitaceous hosts, including *G. bolayi*, *G. orontii*, and *G. tabaci* (Braun *et al.*, 2019; Wagh *et al.*, 2022).

Golovinomyces valerianae (Jacz.) V.P. Heluta

on *Valeriana capitata* Link

foothills, Deep canyon, southwestern slope, 13.04.1945, M.N. Kuznezova.

Note: The species is rare in the Ile-Alatau.

Golovinomyces verbasci (Jacz.) V.P. Heluta

on *Verbascum songaricum* Schrenk

SA, 1500 m a. s. l., 07.09.1937, M.N. Kuznezova; *ibid.*, 23.06.1957, B.K. Kalymbetov;

on *Verbascum* sp.

BA, floodplain forest, 08.08.2011, Y.V. Rakhimova;

KKas, 17.09.2011, Y.V. Rakhimova.

Note: The species is rare in the Ile-Alatau.

Leveillula cylindrospora U. Braun

on *Atriplex sphaeromorpha* Iljin

foothill plain, 24.09.1954, B.K. Kalymbetov;

on *Bassia prostrata* (L.) A. J. Scott (*Kochia prostrata* (L.) Schrad.)

Deep canyon, 09.11.1945, M.N. Kuznezova;

on *Krascheninnikovia ceratoides* (L.) Gueldenst. (*Eurotia ceratoides* (L.) C.A. Mey.)

foothill plain, 24.09.1957, B.K. Kalymbetov.

Note: The species is rare in the Ile-Alatau.



Fig. 6A: *Leveillula duriaei* on *Dracocephalum integrifolium*

Leveillula duriaei (Lév.) U. Braun

on *Dracocephalum bipinnatum* Rupr.

Small Kemin gorge, south slope, Aktyuz, 06.09.1957, B.K. Kalymbetov;

on *Dracocephalum integrifolium* Bunge (Fig. 6A)

Ch, southeast slope, 1350 m a. s. l., 29.08.1957, B.K. Kalymbetov; *ibid.*, southwestern slope, 04.07.2012, Y.V. Rakhimova.

on *Lagochilus diacanthophyllus* (Pall.) Benth.

foothills, Aksai gorge, southwestern slope, 13.08.1939, M.N. Kuznezova;

on *Lagochilus platycalyx* Schrenk

Deep canyon, 06.08.1945, M.N. Kuznezova;

on *Phlomooides pratensis* (Kar. & Kir.) Adylov, Kamelin & Makhm. (*Phlomis pratensis* Kar. et Kir.)

I, 23.08.1939, M.N. Kuznezova;

on *Phlomis* sp.

SA, bank of the Small Almaty River, 15.10.1945, M.N. Kuznezova;

on *Salvia nemorosa* L.

foothills, near the town of Issyk, 18.08.1937, M.N. Kuznezova;

on *Salvia* sp.

UsK, 11.07. 2010, Y.V. Rakhimova.

Note: The species is rare in the Ile-Alatau.

×*Leveillula jaczewskii* U. Braun

on *Dodartia orientalis* L.

I, floodplain of the Issyk River, 1300 m a. s. l., 13.09.1959, B.K. Kalymbetov; footplain, village Lavar, 24.09.1957, B.K. Kalymbetov.

×*Leveillula lactucarum* Durrieu & Rostam

on *Chondrilla* sp.

SA, 15.10.1945, M.N. Kuznezova;

Leveillula lappae (Castagne) U. Braun

on *Cirsium arvense* (L.) Scop.

I, on the way to the lake, 1600 m a. s. l., 14.09.1957, B.K. Kalymbetov;

on *Cirsium oleraceum* (L.) Scop.

SA, 30.07.1939, M.N. Kuznezova;

on *Cousinia* sp.

SA, 10.11.1937, M.N. Kuznezova;

on *Echinops albicaulis* Kar. & Kir.

foothills, Aksai gorge, south-western slopes, 12.08.1939, M.N. Kuznezova; foothills, south-western slopes, 03.10.1939, M.N. Kuznezova; **SA**, southern rocky slope, bank of the Battery River, 1500 m a. s. l.,

10.10.1945, M.N. Kuznezova;

on *Echinops sphaerocephalus* L.

KKas, 2036 m a. s. l., 08.09.2015, Y.V. Rakhimova; on *Inula* sp.

foothills, 15.07.1939, M.N. Kuznezova;

on *Saussurea elegans* Ledeb., *S. salicifolia* (L.) DC. – foothills, Deep canyon, northern slope, 14.09.1938,

M.N. Kuznezova;

Leveillula papilionacearum (Kom.) U. Braun
on *Hedysarum songoricum* Bong. (*Hedysarum montanum* (B. Fedtsch.) B. Fedtsch.)

SA, south slope, 24.08.1953, M.N. Kuznezova;
on *Medicago falcata* L.
foothills, Aksai gorge, 18.08.1939, M.N. Kuznezova;
on *Onobrychis* sp.

Ka, 1351 m a. s. l., 10.06.2011, Y.V. Rakhimova;
on *Thermopsis* sp.

BA, 10.09.1937, M.N. Kuznezova;
on *Vicia tenuifolia* Roth

SA, 14.09.1937, M.N. Kuznezova.

Note: The species is widely distributed on the territory of the Ile-Alatau.

×*Leveillula picridis* (Castagne) Durrieu & Rostam
on *Achillea micrantha* Willd.

foothills, 25.08.1945, L.D. Kazenas;
on *Achillea* sp.

P, near the waterfall, spruce forest, 14.07.2019, U.K. Jetigenova;

on *Artemisia dracunculus* L.

SA, right bank of the Small Almaty River, 1500 m a. s. l., 15.10.1945, M.N. Kuznezova; **I**, 1300 m a. s. l., 12.09.1959, B.K. Kalymbetov; **TB**, 16.08.2012, Y.V. Rakhimova; **BA**, on the way to the lake, 20.08.2008, Y.V. Rakhimova; **Ka**, 03.08.2016, Y.V. Rakhimova; Assy gorge, right bank of the Assy river, 05.08.2012, Y.V. Rakhimova; **KKas**, 29.06.2012, N. Zhakhan; *ibid.*, 17.09.2011, Y.V. Rakhimova; *ibid.*, 08.09.2015, Y.V. Rakhimova;

on ***Artemisia gmelinii* Weber ex Stechm. (*Artemisia sacrorum* Ledeb.)

right bank of the Small Almaty River, pebbles, 15.10.1945, M.N. Kuznezova;

on *Artemisia* sp.

Deep canyon, in the barberry bushes, 1050 m a. s. l., 10.10.1945, M.N. Kuznezova.

×*Leveillula rutae* (Jacz.) U. Braun

on *Haplophyllum* sp.

Deep canyon, southern rocky slope, 13.07.1945, M.N. Kuznezova.

Leveillula taurica (Lév.) G. Arnaud

on *Clematis songarica* Bunge

KKas, 08.09.2015, Y.V. Rakhimova;

on ***Epilobium angustifolium* L. subsp. *angustifolium* (*Chamaenerion angustifolium* (L.) Scop.)

I, on the way to the lake, 28.07.1939, M.N. Kuznezova, *ibid.*, 1600 m a. s. l., 12.09.1959, B.K. Kalymbetov;

on **Hypericum hirsutum* L.

P, near the waterfall, spruce forest, 14.07.2019, U.K. Jetigenova;

on *Peganum harmala* L.

Assy gorge, 05.08.2012, Y.V. Rakhimova; **KKas**, 08.09.2015, Y.V. Rakhimova.

Note: *Leveillula taurica* is most likely a complex of species; revision of samples from Central Asia and Kazakhstan is necessary.

Leveillula verbasci (Jacz.) Golovin

on *Verbascum songaricum* Schrenk

Ch, 27.08.1957, **I**, 12.09.1957, B.K. Kalymbetov;
on *Verbascum* sp.

BA, 29.09.1937, M.N. Kuznezova.

Note: The species is rare in the Ile-Alatau.

Neoerysiphe galeopsidis (DC.) U. Braun

on **Dracocephalum imberbe* Bunge

BA, southwestern slope, 03.09.2018, A.M. Assylbek;
on *Dracocephalum nutans* L. (only anamorph)

SA, 29.08.1946, M.N. Kuznezova;

on *Dracocephalum* sp. (only anamorph)

foothills, Aksai gorge, southwestern slope, 13.07.1939, M.N. Kuznezova;

on *Eremostachys* sp.

eastern slope of Suyktau, 20.06.1955, B.K. Kalymbetov;

on *Galeopsis* sp.

BA, 2111 m a. s. l., 13.08.2009, Y.V. Rakhimova;

on *Lamium album* L.

SA, northern slope, aspen forests, 20.08.1937, M.N. Kuznezova, nature park “Medeo”, a ridge between the river Small Almaty and Butakov, small gorge, northeast slope, 23.06.2020, G. Sypabekkyzy; *ibid.*, western slope, small gorge, deciduous forest, 28.07.2020, Y.V. Rakhimova; **I**, bank of the Issyk lake, 12.09.1957, B.K. Kalymbetov; Small Kemin gorge, 2400 m a. s. l., 06.09.1957, B.K. Kalymbetov; **A**, southeast slope, spruce forest, 27.08.2018, A.M. Assylbek; **BA**, southeast slope, spruce forest, 31.08.2018, Y.V. Rakhimova; *ibid.*, on the way to Kumbel mount, 15.08.2012, Y.V. Rakhimova; **P**, spruce forest, 27.07.2012, Y.V. Rakhimova; *ibid.*, pine forest border, 15.07.2019, L.A. Kyzmetova; **Tu**, on the way to Kairak waterfall, spruce forest, 13.07.2019, L.A. Kyzmetova; **Ka**, surroundings of the village of Izvestkovoe, 19.09.2013, Y.V. Rakhimova; **B**, the confluence of the right tributary with a waterfall in the Butakov river, mixed forest, 07.09.2020, A.M. Assylbek; **KKas**, in the Achnatherum thicket near the stream, 29.06.2012, Y.V. Rakhimova;

on *Leonurus cardiaca* L.

SA, on the slopes of the foothills, 15.08.1937, M.N. Kuznezova;

on *Leonurus tataricus* L.

ZhA, southwest of the village Akterek, 27.06.2014, N. Zhakhan;

on *Leonurus* sp.

Ku, 15.08.2013, Y.V. Rakhimova; 5 km west of Issuk, 23.06.2011, Y.V. Rakhimova;
on *Marrubium vulgare* L.

KKas, 29.06.2012, Y.V. Rakhimova;

on *Nepeta nuda* L. subsp. *nuda* (*N. pannonica* L.)

SA, near Gorelnik, 30.08.1946, M.N. Kuznezova, *ibid.*, 16.08.1957, B.K. Kalymbetov; **Ch**, southwestern slope, 12.09.2010, Y.V. Rakhimova;
on *Origanum vulgare* L.

SA, southeast slope, 05.09.1937, M.N. Kuznezova; *ibid.*, on the way to the Kok-Dzhailau pass, 15.08.2012, Y.V. Rakhimova; **Ch**, 1300 m a. s. l., 29.08.1957, B.K. Kalymbetov, **I**, 1700 m a. s. l., 12.10.1957, B.K. Kalymbetov; **M**, 07.09.2012, Y.V. Rakhimova; **Ku**, 15.08.2013, Y.V. Rakhimova;

on *Phlomis herba-venti* L. subsp. *pungens* (Willd.)

Maire ex DeFilipps (*P. pungens* Willd.)

foothills, 08.04.1946, M.N. Kuznezova;

on *Phlomis* sp.

BA, 14.07.2011, Y.V. Rakhimova; **UzK**, above the dam, 07.07.2010, Y.V. Rakhimova; **Ka**, surroundings of the village of Izvestkovoe, 19.09.2012, Y.V. Rakhimova; **KKas**, 29.06.2012, Y.V. Rakhimova; *ibid.*, 28.06.2012, Y.V. Rakhimova;

on *Phlomoides oreophila* (Kar. & Kir.) Adylov, Kamelin & Makhm.

Ch, western slope, 27.08.1957, B.K. Kalymbetov; **Ku**, southeast slope, 15.08.2013, Y.V. Rakhimova; **ZhB**, 06.07.2016, Y.V. Rakhimova;

on *Phlomoides pratensis* (Kar. & Kir.) Adylov, Kamelin & Makhm.

SA, 04.04.1956, B.K. Kalymbetov, nature park “Medeo”, a ridge between the river Small Almaty and Butakov, western slope, small canyon, deciduous forest, 28.07.2020, G.A. Urmanov; **Ch**, western slope, 27.08.1957, B.K. Kalymbetov;

on *Phlomoides speciosa* (Rupr.) Adylov, Kamelin & Makhm.

ZhB, 06.07.2016, Y.V. Rakhimova;

on *Phlomoides tuberosa* (L.) Moench

between the Maitobe and Araltobe mountains, 2500 m a. s. l., 01.09.1957, B.K. Kalymbetov;

on *Thymus* sp.

BA, on the rocks, 20.08.2008, Y.V. Rakhimova.

Note: The species is widely distributed on the territory of the Trans-Ili Alatau (especially on *Lamium album*).

Neoerysiphe galii (S. Blumer) U. Braun

on *Asperula* sp.

Chilik gorge, 10.07.1948, S.R. Shvartzman;

on *Galium spurium* L. (Fig. 7A)

between the Maitobe and Araltobe mountains, 2300 m a. s. l., 02.09.1957, B.K. Kalymbetov; **M**, 07.09.2012, Y.V. Rakhimova; **B**, right tributary of the Butakov river, coniferous forest, 07.09.2020, Y.V. Rakhimova.

Note: The species is rare in the Ile-Alatau.



Fig. 7A: *Neoerysiphe galii* on *Galium spurium*

× *Neoerysiphe hiratae* V.P. Heluta & S. Takam.

on *Ligularia macrophylla* (Ledeb.) DC.

A, southeast slope, spruce forest, 27.08.2018, L.A. Kyzmetova; **SA**, on the way to Kok-Dzhailau pass, birch forest, 19.08.2019, U.K. Jetigenova; *ibid.*, 15.08.2012, Y.V. Rakhimova; *ibid.*, the bank of Kazachka river, aspen-spruce forest, 02.09.1937, M.N. Kuznezova; *ibid.*, nature park “Medeo”, a ridge between the river Small Almaty and Butakov, western slope, small canyon, deciduous forest, 28.07.2020, Y.V. Rakhimova; *ibid.*, small canyon, below the Samal complex, northwest slope, deciduous forest, 28.07.2020, Y.V. Rakhimova; **Ku**, southeast slope, 15.08.2013, Y.V. Rakhimova; **I**, eastern slope, 1500 m a. s. l., 14.09.1957, B.K. Kalymbetov; **OK**, 20.09.2012, G.A. Nam; **B**, deciduous forest, 30.06.2020, U.K. Jetigenova; *ibid.*, the confluence of the right tributary with the waterfall in the Butakov river, mixed forest, 07.09.2020, A.M. Assylbek.

Note: The species is widely distributed on the territory of the Ile-Alatau.

× *Phyllactinia betulae* (DC.) Fuss

on *Betula pendula* Roth subsp. *pendula* (*B. verrucosa* Ehrh.)

SA, southeast slope, 18.09.1937, M.N. Kuznezova;

on *Betula tianschanica* Rupr.

SA, northern slope, 07.10.1938, M.N. Kuznezova, **Ta**, 06.10.1954, S.R. Shvartzman.

× *Phyllactinia fraxini* (DC.) Fuss

on *Fraxinus sogdiana* Bunge

on the way to **SA**, 07.10.1938, M.N. Kuznezova;

Note: The species is rare in the Ile-Alatau.

× *Phyllactinia hippophaës* Thüm. ex S. Blumer

on *Hippophae rhamnoides* L.

BA, in the floodplain, 06.09.2011, Y.V. Rakhimova.

Phyllactinia mali (Duby) U. Braun
on ****Crataegus chlorocarpa** Lenné & C. Koch (*C. altaica* Lange)

SA, south slope, 19.08.1938, M.N. Kuznezova;
on *Crataegus* sp.
foothills, Deep canyon, northwestern slope, 10.10.1945,
M.N. Kuznezova, **SA**, 13.10.1954, I.N. Golovenko.

***Phyllactinia populi** (Jacz.) Y.N. Yu

on *Populus nigra* L.

SA, 07.10.1938, M.N. Kuznezova.

Note: The species is widely distributed on the territory of the Ile-Alatau.

***Phyllactinia pyri-serotinae** Sawada

on *Cotoneaster multiflorus* Bunge

SA, southeast slope, 23.08.1945, M.N. Kuznezova.

Podosphaera aphanis (Wallr.) U. Braun & S. Takam.

var. *aphanis*

on *Agrimonia eupatoria* L.

SA, 18.06.1937, M.N. Kuznezova;

on ****Agrimonia eupatoria** subsp. *asiatica* (Juz.) Skalický (*A. asiatica* Juz.)

BA, crest of Big Almaty peak, pine forest edge, 30.08.2018, Y.V. Rakhimova; nature park “Medeo”, **B**, western slope, deciduous forest, 21.08.2020, G.A. Urmanov; Kimasar gorge, above the forester's house, 09.09.2020, Y.V. Rakhimova;

on *Agrimonia* sp.

SA, on the way to the Kok-Dzhailau pass, 1960 m a. s. l., 15.08.2012, Y.V. Rakhimova;

on *Alchemilla cyrtopleura* Juz.

Small Kemin gorge, 2300 m a. s. l., 04.09.1957, B.K. Kalymbetov;

on *Alchemilla retropilosa* Juz.

between the Maitobe and Araltobe mountains, 2500 m a. s. l., 01.09.1957, B.K. Kalymbetov;

on *Alchemilla sibirica* Zamelis

BA, southeast slope, juniper woodlands, 04.09.2018, U.K. Jetigenova;

on *Alchemilla xanthochlora* Rothm. (*A. vulgaris* L.)

BA, 18.08.1948, S.R. Shvartzman;

on *Alchemilla* sp.

A, eastern slope, spruce forest, 28.08.2018, A.M. Assylbek; **M**, 07.09.2012, Y.V. Rakhimova; **SA**, the pass below Kumbel peak, 16.08.2012, Y.V. Rakhimova; **Tu**, right bank of the Kishi-Turgen river, 02.08.2016, Y.V. Rakhimova; *ibid.*, spruce forest border, 18.08.2019, Y.V. Rakhimova; **OK**, 20.09.2012, G.A. Nam; **Ka**, surroundings of the village of Izvestkovo, 19.09.2012, Y.V. Rakhimova; **ZhB**, central part of gorge, 06.07.2016, Y.V. Rakhimova; **B**, in the vicinity of the Upper Butakov waterfall, coniferous forest, 09.09.2020, B.Y. Dzhunuskanova; *ibid.*, a tributary of Butakov river, coniferous forest, 07.09.2020, Y.V. Rakhimova;

on *Geum urbanum* L.

Assy gorge, right bank of the Assy river, 05.08.2012, Y.V. Rakhimova; **BA**, floodplain forest, 08.08.2011, Y.V. Rakhimova; **Ka**, surroundings of the village of Izvestkovo, 19.09.2012, Y.V. Rakhimova; nature park “Medeo”, a ridge between the river Small Almaty and Butakov, western slope, small canyon, deciduous forest, 28.07.2020, Y.V. Rakhimova; *ibid.*, **B**, western slope, deciduous forest, 21.08.2020, E.S. Sametova; **KKas**, 08.09.2015, Y.V. Rakhimova;

on *Potentilla chrysantha* Trevir. subsp. *chrysantha* (*P. asiatica* (Th. Wolf) Juz.)

BA, western slope, spruce forest, 05.09.2018, Y.V. Rakhimova;

on *Potentilla multifida* L.

BA, on the way to the lake, 20.08.2008, Y.V. Rakhimova;

on *Potentilla nivea* L.

SA, 03.08.1937, M.N. Kuznezova;

on *Potentilla pedata* Willd.

ZhB, 06.07.2016, Y.V. Rakhimova;

on *Potentilla reptans* L.

SA, 30.07.1946, M.N. Kuznezova;

on *Potentilla* sp.

ZhB, lower part of gorge, 06.07.2016, Y.V. Rakhimova; *ibid.*, **ZhA**, 26.06.2014, N. Zhakhan.

Note: The species is widely distributed on the territory of the Ile-Alatau.

Podosphaera aucupariae Erikss.

on *Sorbus tianschanica* Rupr.

SA, 24.10.1937, M.N. Kuznezova.

Note: The species is rare in the Ile-Alatau.

Podosphaera clandestina (Wallr.) Lév. var. *clandestina*

on ****Crataegus** × *dsungarica* Zabel ex Lange (*Crataegus* × *almaatensis* Pojark.)

SA, 22.10.1937, M.N. Kuznezova.

Note: The species is rare in the Ile-Alatau.

Podosphaera codonopsidis (Golovin) U. Braun

on *Codonopsis clematidea* (Schrenk) C.B. Clarke

Small Kemin gorge, Aktyuz, 2300 m a. s. l., 04.09.1957, B.K. Kalymbetov; **SA**, spruce forest, 00.09.1937, M.N. Kuznezova.

Note: The species is rare in the Ile-Alatau.

Podosphaera dipsacacearum (Tul. & C. Tul.) U. Braun & S. Takam.

on *Dipsacus azureus* Schrenk

foothills, Almaty, 04.08.1945, L.D. Kazenas;

on *Dipsacus sativus* (L.) Honck.

foothills, Aksai gorge, 16.07.1939, M.N. Kuznezova;

on *Dipsacus* sp.

UzK, above the dam, 07.07.2010, Y.V. Rakhimova;

on ****Lomelosia songarica** (Schrenk) Soják (*Scabiosa songarica* Schrenk)

foothills, Deep canyon, 13.07.1945, M.N. Kuznezova.

on *Scabiosa* sp.
Kemin gorge, 1960, N.A. Gamalzikaya.
Note: The species is rare in the Ile-Alatau.

Podosphaera epilobii (Wallr.) de Bary
on ***Epilobium cylindricum* D. Don (*E. tianschanicum* Pavlov) (only anamorph)
Chilik gorge, 15.07.1948, Yu.D. Portnykh;
on *Epilobium hirsutum* L. (Fig. 8A)
SA, along the banks of streams, 17.09.1937, M.N. Kuznezova; **A**, eastern slope, spruce forest, 28.08.2018, A.M. Assylbek; **Tu**, at the confluence of the tributary with the Bear waterfall, 27.07.2017, Y.V. Rakhimova; *ibid.*, on the way to the Bear waterfall, 12.07.2019, L.A. Kyzmetova;
on *Epilobium* sp.
SA, 20.04.1946, M.N. Kuznezova; **UzK**, above the dam, 07.07.2010, B.D. Yermekova.
Note: The species is rare in the Ile-Alatau.



Fig. 8A: *Podosphaera epilobii* on *Epilobium hirsutum*



Fig. 9A: *Podosphaera euphorbiae* on *Euphorbia yaroslavii*

Podosphaera euphorbiae (Castagne) U. Braun & S. Takam.

on ***Euphorbia esula* subsp. *tommasiniana* (Bertol.) Kuzmanov (*E. jaxartica* (Prokh.) Krylov)

Ta, 23.10.1940, L.D. Kazenas;

on *Euphorbia soongarica* Boiss.

SA, northern slope, 13.09.1937, M.N. Kuznezova;

on *Euphorbia yaroslavii* Poljakov (Fig. 9A)

Ch, 22.04.2007, Y.V. Rakhimova.

on *Euphorbia* sp.

SA, bank of the Battery River, 15.10.1945, M.N. Kuznezova.

Note: The species is rare in the Ile-Alatau.

Podosphaera ferruginea (Schltdl.) U. Braun & S. Takam. var. *ferruginea*

on *Sanguisorba officinalis* L.

SA, 18.10.1938, M.N. Kuznezova; *ibid.*, bank of the Battery River, 29.09.1939, M.N. Kuznezova; *ibid.*, Toadstool gorge, 2000 m a. s. l., 26.08.1953, B.K. Kalymbetov; nature park “Medeo”, a ridge between the river Small Almaty and Butakov, small gorge, below the Samal complex, northwest slope, deciduous forest, 14.06.2020, A.M. Assylbek; *ibid.*, northeast slope, 23.06.2020, A.M. Assylbek; *ibid.*, **B**, western slope, deciduous forest, 21.08.2020, G.A. Urmanov;

on *Sanguisorba* sp.

SA, 18.06.1938, M.N. Kuznezova.

Note: The species is widely distributed on the territory of the Ile-Alatau.

Podosphaera fugax (Penz. & Sacc.) U. Braun & S. Takam.

on *Geranium collinum* Stephan ex Willd.

SA, 20.07.1957, B.K. Kalymbetov; foothills, Deep canyon, 07.05.1945, M.N. Kuznezova; **A**, eastern slope, spruce forest, 28.08.2018, L.A. Kyzmetova; *ibid.*, southeast slope, 27.08.2018, U.K. Jetigenova;

on ***Geranium linearilobum* DC. in Lam. & DC. (*G. transversale* (Kar. & Kir.) Vved.)

foothills, Deep canyon, southeast slope, 07.05.1945, L.D. Kazenas;

on *Geranium rectum* Trautv.

SA, 25.07.1957, B.K. Kalymbetov;

on *Geranium tuberosum* L.

foothills, Deep canyon, southeast slope, 07.05.1945, M.N. Kuznezova;

on *Geranium* sp.

P, spruce forest, 27.07.2012, Y.V. Rakhimova; **BA**, crest of Big Almaty peak, deciduous forest, 01.07.2020, G.A. Urmanov; nature park “Medeo”, a ridge between the river Small Almaty and Butakov, small gorge, below the Samal complex, northwest slope, deciduous forest, 14.06.2020, G. Sypabekkyzy.

Note: The species is widely distributed on the territory of the Ile-Alatau.



Fig. 10A: *Podosphaera fuliginea* on *Veronica chamaedrys*

×*Podosphaera fuliginea* (Schltld.) U. Braun & S. Takam.

on **Veronica chamaedrys* L. (Fig. 10A)

A, eastern slope, spruce forest, 27.08.2018, U.K. Jetigenova.

on *Veronica* sp.

B, the confluence of the right tributary with a waterfall in the Butakov river, mixed forest, 07.09.2020, A.M. Assylbek.

Note: The species is rare in the Ile-Alatau.

Podosphaera erigerontis-canadensis (Lév.) U. Braun on *Crepis sibirica* L.

SA, bank of the Battery river, 11.09.1937, M.N. Kuznezova, *ibid.*, northwestern slope, bank of the Kazachka river, 11.09.1937, M.N. Kuznezova;

on *Erigeron acris* L.

SA, 31.08.1946, M.N. Kuznezova;

on *Taraxacum officinale* Weber ex Wiggins

SA, right bank of the Kazachka river, 17.10.1937, M.N. Kuznezova; foothills, Deep canyon, south slope, 22.05.1945, M.N. Kuznezova;

on *Taraxacum* sp.

Deep canyon, 22.05.1945, M.N. Kuznezova; **Ch**, 27.08.1957, 1300 m a. s. l., B.K. Kalymbetov; **BA**, northwestern slope, mixed forest, 06.09.2018, U.K. Jetigenova; **A**, southeast slope, spruce forest, 27.08.2018, U.K. Jetigenova; Assy gorge, right bank of the Assy river, 06.08.2012, Y.V. Rakhimova; **Ka**, 03.08.2016, Y.V. Rakhimova; *ibid.*, 10.06.2011, Y.V. Rakhimova; foothills, 5 km west of Issyk, 23.06.2011, Y.V. Rakhimova.

Note: The species is widely distributed on the territory of the Ile-Alatau. *Podosphaera erigerontis-canadensis* is most likely a complex of species; revision of samples from Central Asia and Kazakhstan is necessary.

Podosphaera leucotricha (Ellis & Everh.) E.S. Salmon.

on *Malus sieversii* (Ledeb.) M. Roem.

BA, western slope, spruce forest border, 23.05.2019, Y.V. Rakhimova; *ibid.*, northern slope, spruce forest, 23.05.2019, L.A. Kyzmetova; nature park “Medeo”, a ridge between the river Small Almaty and Butakov, small gorge, northern slope, deciduous forest, 26.05.2020, Y.V. Rakhimova; *ibid.*, 26.05.2020, A.M. Assylbek; *ibid.*, western slope, small gorge, deciduous forest, 28.07.2020, G.A. Urmanov; **Ka**, 5 km above the ecopost, at the base of the slope, 07.07.2010, Y.V. Rakhimova; **UsK**, 15.05.2010, Y.V. Rakhimova; **Ku**, southeast slope, 15.08.2013, Y.V. Rakhimova; **Tu**, at the confluence of the tributary with the Bear waterfall, 27.07.2017, Y.V. Rakhimova; **ZhA**, 27.06.2014, A.K. Dzhienbekov;

on *Malus* sp.

SA, on the way to the Medeo, apple tree forest, 18.09.1939, M.N. Kuznezova, foothills, Deep canyon, apple tree forest, 13.07.1945, M.N. Kuznezova.

Note: The species is widely distributed on the territory of the Ile-Alatau.

Podosphaera macularis (Wallr.) U. Braun & S. Takam. on *Humulus lupulus* L.

SA, 03.08.1937, M.N. Kuznezova; **A**, southeast slope, 27.08.2018, Y.V. Rakhimova; **UzK**, 07.07.2010, B.D. Yermekova; **Ku**, 15.08.2013, Y.V. Rakhimova.

Note: The species is quite widespread in the Ile-Alatau.

Podosphaera mors-uvae (Schwein.) U. Braun & S. Takam.

on *Ribes meyeri* Maxim.

P, spruce forest, 27.07.2012, Y.V. Rakhimova.

on ***Ribes uva-crispa* var. *sativum* DC. (*Grossularia reclinata* (L.) Mill.)

surroundings of Almaty, 20.07.1953, S.R. Shvartzman.

Note: The species is rare in the Ile-Alatau.

Podosphaera pannosa (Wallr.) de Bary

on *Persica vulgaris* Mill.

foothills, Deep canyon, 09.11.1945, S.R. Shvartzman.

on *Rosa spinosissima* L.

foothills, Aksai gorge, 14.08.1939, M.N. Kuznezova;

on *Rosa* sp. (Fig. 11A)

UzK, above the dam, 07.07.2010, Y.V. Rakhimova; **ZhA**, 26.06.2014, Y.V. Rakhimova;

Note: The species is rare in the foothills of the Ile-Alatau.

×*Podosphaera phtheiospermi* (Henn. & Shirai) U. Braun & T.Z. Liu

on *Euphrasia* sp.

BA, on the way to the lake, 13.08.2009, Y.V. Rakhimova;

on ***Pedicularis anthemifolia* subsp. *elatior* (Regel)

P. C. Tsoong (*P. macrochila* Vved.)

I, 14.07.1946, M.N. Kuznezova;

on *Pedicularis songarica* Schrenk ex Fisch. & C. A. Mey.

SA, on the bank of the Battery River, 29.07.1946, M.N. Kuznezova;

on *Pedicularis* sp.

SA, on the way to the Talgar pass, 26.07.1946, M.N. Kuznezova.

Note: The species is rare in the Ile-Alatau.



Fig. 11A: *Podosphaera pannosa* on *Rosa* sp.,



Fig. 12A: *Podosphaera tridactyla* sensu lato on *Prunus prostrata* var. *concolor*

Podosphaera plantaginis (Castagne) U. Braun & S. Takam.

on *Plantago lanceolata* L.

foothills, Aksai gorge, 28.07.1939, 28.07.1938, M.N. Kuznezova; *ibid.*, 17.09.1940, L.D. Kazenas;

on *Plantago major* L.

SA, on the way to the Kumbel peak, 05.10.1938, M.N. Kuznezova.

Note: The species is rare in the Ile-Alatau.

Podosphaera polemonii (L. Junell) U. Braun & S. Takam.

on *Polemonium caeruleum* L.

SA, 17.09.1937, M.N. Kuznezova; **P**, spruce forest, 27.07.2012, Y.V. Rakhimova; **Ka**, surroundings of the village of Izvestkovoe, 19.09.2012, Y.V. Rakhimova.

Note: The species is rare in the Ile-Alatau.

Podosphaera tridactyla (Wallr.) de Bary s. l.
on *Prunus prostrata* var. *concolor* (Boiss.) Lipsky
(*Cerasus tianschanica* Pojark.) (Fig. 12A)

Aksai gorge, bank of the Aksai River, 05.09.1937, M.N. Kuznezova; **Ch**, in the floodplain of Chemolgan river, 12.09.2010, Y.V. Rakhimova.

on *Prunus padus* L. subsp. *padus* (*Padus avium* Mill., *P. racemosa* (Lam.) Gilib.)

SA, on the way to the Medeo (apricot grove), 19.09.1934, 17.09.1937, M.N. Kuznezova; **I**, forest above the lake, 29.08.1939, M.N. Kuznezova, foothills, fruit zone, L.D. Kazenas, 1953.

Note: Based on morphological studies and analysis of molecular sequences, some authors (Meeboon *et al.*, 2020) propose to divide the complex species *P. tridactyla* s. lat. for 10 species, including 7 new species (*P. ampla*, *P. pruni-avium*, *P. pruni-cerasoidis*, *P. prunigena*, *P. pruni-lusitanicae*, *P. prunina* и *P. pruni-japonicae*) and 3 known species (*P. longiseta*, *P. salatai* и *P. tridactyla* s. str.). *Podosphaera tridactyla* is most likely a complex of species; revision of samples from Central Asia and Kazakhstan is necessary.



Fig. 13A: *Podosphaera xanthii* on *Xanthium strumarium*

Podosphaera xanthii (Castagne) U. Braun & Shishkoff

on *Bidens tripartita* L.

floodplain of the Kaskelen river, 09.09.1939, M.N. Kuznezova;

on *Cucurbita pepo* L.

foothill plain, in the vicinity of the Lavar village, 24.09.1957, B.K. Kalymbetov;

on *Xanthium strumarium* L. (Fig. 13A)

foothills, in the vicinity of the village of Chilik, 24.09.1957, B.K. Kalymbetov; *ibid.*, in the vicinity of the village of Tausamal, 26.07.2018, Y.V. Rakhimova.

Note: The species is rare in the foothills of the Ile-Alatau.

Sawadaea bicornis (Wallr.) Homma (*Uncinula aceris* (DC.) Sacc.)

on *Acer negundo* L.

foothills, in the vicinity of the village of Tausamal, 26.07.2018, Y.V. Rakhimova; **P**, floodplain of the river, 16.07.2019, L.A. Kyzmetova; nature park “Medeo”, a ridge between the river Small Almaty and Butakov, small gorge, north slope, 26.05.2020, Y.V. Rakhimova; *ibid.*, small canyon below the Samal complex, northwest slope, deciduous forest, 14.06.2020, G. Sypabekkyzy.

Note: The species develops annually on maple leaves in the foothills of the Ile-Alatau.

Excluded doubtful and insufficiently known taxa

Sphaerotheca fuliginea f. *serratula* Kalymb. on *Klasea sogdiana* (Bunge) L. Martins (*Serratula sogdiana* Bunge, *S. alata* C. A. Mey.)

Suyktau, right bank of a mountain river, 17.06.1955, B. K. Kalymbetov.