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Environmental analysis of Upper Alpine rock-and-talus flora of central and eastern parts of the Russia's Caucasus Region

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Abstract. The paper presents the results of a detailed environmental analysis of the Upper Alpine rock-and-talus flora of the central and eastern parts of the Russia's Caucasus Region. The classification of petrophytes (obligate, facultative and contingent) with respect to the acidity of the substrate (oxylophiles, xylo-calciphiles, calciphiles) and with regard to the substrate type (rupestrophytes, lapidophytes, schistophytes, lapishistophytes, morenophytes, glareophytes) is given. The species, quantity and percentage of each environmental group are indicated. The dominance in the studied flora with respect to acidity of the substrate of oxylophytes is noted, along with the physical state - lapishistophytes. In terms of the physical properties of the substrate, the flora species represent quite complex aggregate formed by stenotopic and environmentally plastic species settling on two to three, less often on four types of the substrate.

1. Introduction

The high-mountain flora of the Russia's Caucasus Region is classified as original carrier of a unique gene pool having multiple endemic species. The composition of this flora includes high mountain complexes characterized by confinedness to rocky substrates with unique floristic composition. One such territory is the high mountain part of the northern macro slope of the central and eastern parts of the Russia's Caucasus Region, which large territories remain little studied due to the inaccessibility of multiple alpine massifs. This flora presents a particular interest as an indicator of intense species formation, which is demonstrated by the presence of narrow-lobed endemic species and members of monotype endemic genera, the study of which can make a significant contribution to the adjustment of the florogenesis model of the high-mountain Caucasus flora.

This task represents part of the current global challenge of studying and preserving biodiversity, which is now becoming increasingly important. The inventory and analysis of the flora of this territory is the basis for assessing the state of phytobiota, determining the trends of its change and influence on the integrity of the habitat of this flora, making forecasts in many theoretical and practical fields.

The study of the flora of the specified territory from these perspectives is important to make recommendations for the rational use of plant resources, as well as to forecast the effects of human influence on the phytobiota of the highlands. From this point of view, the thesis research seems quite relevant.

2. Object and methods of study

The object of the study was rock-and-talus flora of the highlands of the central and eastern parts of the Russia's Caucasus Region. The material for the study was obtained as a result of observations in



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nature and collection of herbal material during expeditions from 2003 to 2017. The main highlands of Kabardino-Balkaria (Elbrus, Donguz-orun), North Ossetia-Alania (Kazbek), Chechnya, Ingushetia, Dagestan and some parts of northern Georgia were repeatedly visited. All of the above routes are mainly covered with hard-to-reach highlands.

In total, about 2,500 herbal samples were collected. The herbarium funds of the Herbarium of the Komarov Botanical Institute of the Russian Academy of Sciences (LE), Moscow State University (MW), Southern Federal University (RWBG), Dagestan State University (LENUD), Kabardino-Balkar State University (KBHG-AUBUSH), Ingush State University (INGU), Mountain Botanical Garden of Dagestan Federal Research Center of RAS (DAG), North Ossetia Nature Reserve. The lists of species types from altitudes from 2900 m to 3900-4000 m above sea level in various parts of the central and eastern parts of the Russia's Caucasus Region were compiled on the basis of label data.

Standard methods according to A.I. Galushko [1] were used for ecological analysis of flora. The analysis of biomorphs was given according to the classifications of K. Raunkiaer [2] and G.I. Serebryakov [3]. The monotypic concept of species was taken as a theoretical basis. Scientific (Latin) names of species, genera and families are given according to S.K. Cherepanov [4].

3. Results and discussion

Several types of habitats demonstrating diverse ecological setting of the studied territory can be identified within the subniveal belt. These are rocks, talus deposits, slopes covered with crushed stone and rocky slopes, moraines and pebble beds.

The above habitats were most developed in the highlands of the Main and Side Ranges, to a lesser extent - in the Front Range, along the southern slopes of which there are considerable ledge rocks across the river canyons cutting this range.

In view of the above, it can be argued that plant species living in such conditions belong to petrophytes. Based on the characteristics of the substrate where they live, they are divided into three groups [5, 6]:

- obligate species – petrophytes, living only on the listed habitats and within the subniveal belt, sometimes getting into the alpine belt when it has the corresponding substrate. They are divided into hasmophytes (rock plants), lapidophytes (alluvial plants), shistophytes (talus plants), morenophytes (plants of glacier-free territories), glareophytes (alluvial plants);

- facultative species – can behave as petrophytes settling on all the above substrates, additionally there is a group of lapishistophytes (plants of rocky and crushed habitats). These species may also occur outside rocky substrates, as part of meadow phytocenoses;

- contingent species – non-petrophilous plants, which live in a subniveal belt on grass-covered substrates or in humid habitats.

Another ecological indicator of plant habitat in the subniveal belt is their ratio to substrate acidity determined by the percentage of silica in the rock. Acid rocks are rocks rich in silica, base rocks are rocks not having enough silica, but enriched with calcium, magnesium, iron oxides. Three groups of species are also identified here: oxylophiles living on acid crystal rocks; calciphiles that live on base rocks; oxylo-calciphiles that may occur on any of them.

Within the studied territory the acid rocks are concentrated in the axial part, the Main and Side Ranges are rich with silicate rocks – granite, gneiss, Paleozoic shale; the base rocks are mainly concentrated to the north of the axial zone, on the Front Range and its braces rich with carbonate rocks – Upper Jurassic limestone, marls, dolomites. However, it should be noted that in the extreme conditions of the subalpine and alpine belts, the strict confinedness of species to the acidity of the substrate may be disrupted, and the main role is played not so much by the chemical composition but by the physical state of the substrate (crushed stone, mobility, moisturization, slope exposure and the associated temperature regime, etc.). In lower horizons, this pattern can be traced quite clearly. The same holds true for obligate species with respect to the physical nature of the substrate. It varies widely, and there is no strict confinedness to a certain state of the substrate at the upper distribution boundary [7-10].

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The distribution of species by ecological groups with respect to the acidity of the substrate is shown in Table 1. It shows that rather more than 2/3 species (81.8%) belong to oxylophiles, while a minor part (6.5%) are calciphiles. There are 45 (11.8%) species that are indifferent to the acidity of the substrate.

Table 1. Ecological groups of plants of the Upper Alpine rock-and talus flora of the central and eastern parts of the Russia's Caucasus Region with respect to the acidity of the substrate

Ecological group	Number of species	%
Oxylophiles	314	81.8
Oxylo-calciphiles	45	11.8
Calciphiles	25	6.5
Total:	384	100

The distribution of species with respect to the physical state of the substrate is shown in Table 2.

Table 2. Ecological groups of plants of the Upper Alpine rock-and talus flora of the central and eastern parts of the Russia's Caucasus Region in relation to the physical composition of the substrate

Ecological group by confinedness to the substrate type	Number of species			
-	OB^1	FC	СТ	total
Rupestrophites	45	1	2	48
Rupestro-lapidophytes	3	-	-	3
Rupestro-shistophytes	10	1	-	11
Rupestro-morenophytes	10	-	-	10
Rupestro-lapido-shistophytes	5	-	-	5
Rupestro-lapido-shisto-morenophytes	1	-	-	1
Rupestro-lapishistophytes	4	1	-	5
Rupestro-lapido-morenophytes	4	-	-	4
Rupestro-shisto-morenophytes	5	-	-	5
Total rupestrophites	87	3	2	92
Lapidophytes	5	6	1	12
Lapido-shistophytes	9	1	-	10
Lapido-morenophytes	2	1	-	3
Lapido-shisto-morenophytes	13	3	-	16
Total lapidophytes	29	11	1	41
Shistophytes	28	-	3	31
Shisto-morenophytes	17	11	-	28
Shisto-glareophytes	2	-	-	2
Shisto-moreno-glareophytes	1	_	-	1
Total shistophytes	48	11	3	62
Lapishistophytes	38	71	32	141
Lapishisto-morenophytes	12	23	4	39
Lapishisto-glareophytes	1	6	-	7
Total lapishistophytes	51	100	36	187
Morenophytes	-	1	-	1
Moreno-glareophytes	1	-	-	1
Total morenophytes	1	1	-	2
Total	215	128	41	384

¹OB – obligate; FC – facultative; CT – contingent

Rupestrophites – species that live on rocks, in their depressions, cracks, cavities, etc. There are 48 of them, the vast majority of which (45 species) are eurupestrophytes ("real rupestrophites") living

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only on rocks. These are 6 species of ferns (five species of Aspleniaceae and Woodsia fragilis families), Dianthus cretaceus, Gypsophila imbricata, Draba bryoides, Sempervivum caucasicum, Sedum involucratum, Saxifraga scleropoda, Potentilla divina, Astragalus levieri, Campanula argunensis, Jurinea filicifolia, etc. Facultatively on rocks there are Lloydia serotina, and among contingent species there is Carex obtusata.

Lapidophytes – species that live on large rocky non-mobile alluvial deposits. There are 12 eulapidophytes, from which 5 – obligate (*Polystichum lonchitis, Cryptogramma crispa, Juniperus depressa, Silene caucasica, Noccaea pumila*), 6 – facultative (*Athyrium alpestre, Gymnocarpium dryopteris, G. robertianum, Botrychium lunaria, Oberna pubicaulis, Chaerophyllum rose*) and 1 contingent – *Dryopteris oreades*.

Besides rocky types, the studied flora is also characterized by the types living not only on rocks, but also on other stony substrates – alluvial deposits, taluses, moraines, etc., in total 9 combinations (Table 2).

Most of them are rock-and-talus (11 species: *Cerastium daghestanicum, Minuartia brotheriana, Draba bruniifolia, Saxifraga ruprechtiana, Potentilla nivea*, etc.) and rock-moraines (10 species: *Charesia akinfievii, Minuartia imbricata, Alchemilla chlorosericea, Potentilla brachypetala, Valeriana jelenevskji*, etc.). The total number of rupestrophytes was 92 species, which is 24% of the total flora studied (Table 3).

With other types of habitats lapidophytes form 8 combinations, the largest of which are the alluvial-talus amounting to 10 species such as *Corydalis alpestris* and 2 other species of this genus, *Androsace lechmaniana, Dentaria bipinnata, Cynoglossum holosericeum, Alchemilla elisabethae*, etc. In total there are 54 lapidophyte species (14%). The results are shown in Table 3.

Shistophytes – species that live on dynamic-moving taluses. There are 31 species of eushistiophytes settling only on this type of substrate, most of them are obligate: *Ranunculus arachnoideus, R. tebulossicus, Minuartia aizoides, Oberna lacera, Silene humilis, Apterigia pumila, Didymophysa aucheri, Erysimum babadagensis, Sedum stevenianum, Vavilovia formosa*, etc. Among contingent there is *Epilobium algidum* and 2 other species of this genus. The total number of shistophytes combined with other types of substrate – 84 species (22%), the largest combination – talus-moraine, 17 species: *Delphinium caucasicum, Androsace raddeana, Viola minuta, Draba siliquosa, Erysimum subnivale*, etc.

Lapishistophytes are inhabitants of rocky-crushed substrates. The largest group amounts to 141 species, of which half are facultative (71 species), the rest – obligate (38 species) and contingent (32 species). Obligate eulapishistophytes are represented by such species as *Pulsatilla violacea, Ranunculus trisectilis, Papaver lisae, Arenaria holostea, Sagina saginoides, Silene lychnidea, Salix kazbekensis, Alyssum gehamense*, etc. Among the facultative the most typical are *Pulsatilla albana, Ranunculus caucasicus, Polygonum panjutinii, Rumex acetoselloides, Empetrum caucasicum, Hedysarum caucasicum, Trifolium canescens, Polygala alpicola, Carum alpinum,* etc. Contingent species: *Aconitum confertiflorum, Anemonastrum fasciculatum, Polygonum aviculare, Rhododendron caucasicum, Vaccinium myrtillus, Rhynchocorys elephas, Leontodon hispidus,* etc. In general, lapishistophytes in combination with other types of substrates make 192 species, i.e. 50% of the studied flora is associated with this type of substrate (Table 3).

Table 3. Percentage of ecological groups of plants of the Upper Alpine rock-and talus flora of the central and eastern parts of the Russia's Caucasus Region

Ecological group	Number of species	%
Rupestrophites	92	24
Lapidophytes	54	14
Shistophytes	84	22
Lapishistophytes	192	50
Morenophytes	109	28
Glareophytes	11	3
Total:	542	141

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Morenophytes are plants that settle on moraines. Eumarenophyte is just one – facultative *Plantago* saxatilis, but combined with other types of the substrate the morenophytes amount to 109 species (28%). Most of the species are rocky-crushed-moraine (39): Astragalus alpinus, Vicia alpestris, Chamaesciadium acaule, Valeriana alpestris, Antennaria caucasica, Alopecurus dasyanthus, Catabrosella variegata, Trisetum spicatum, etc.

Glareophytes are plants that settle on pebble beds. There are no euglareophytes. The total number of glareophytes is 11 – Papaver oreophilum, Eunomia rotundifolia, Sobolewskia caucasica, Murbeckiella huetii, Sedum tenellum, etc.

Clearly, the ratio of ecological groups of the studied flora plants is shown in Figure 1. The diagram shows that the territory is mostly covered with lapishistophytes (192 species, 50%), which dominate by the number of species of one habitat (eulapishistophytes). Morenophytes hold the second place (109 species, 28%), while rupestrophytes (92 species, 24%) – the third. There are slightly less shistophytes (84 species, 14%) and lapidophytes (54 species, 14%). The least of all are glareophytes (11 species, 3%).

The diagram also shows that the stenotopic species (ss) are arranged in the following sequence: lapishistophytes (141) – rupestrophytes (48) – shistophytes (31) – lapidophytes (12) – morenophytes (1). There are no stenotopic glareophytes in the studied flora.



Figure 1. Ratio of ecological groups of plants of the Upper Alpine rock-and-talus flora of the central and eastern parts of the Russia's Caucasus Region according to the physical nature of the substrate.

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4. Conclusion

Thus, in the Upper Alpine rock-and-talus flora of the central and eastern parts of the Russia's Caucasus Region, oxylophytes dominate with respect to the acidity of the substrate, and lapishistophytes dominate with regard to the physical condition. In general, in terms of the latter characteristic, the flora species represent quite complex aggregate formed by stenotopic and environmentally plastic species settling on two to three, less often on four types of the substrate, which explains the fact that the total number of species (Table 3) is significantly larger than the total flora list.

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