

Current State of Populations of *Rhodiola Rosea* L. (Crassulaceae) in East Kazakhstan

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Abstract

Background: Based on world experience, first, a modern assessment of the flora is needed to develop strategies and tactics for the conservation of ecosystems of rare and endangered plant species. A regional and global biodiversity strategy should focus on assessing the current state of bioresources. In this regard, to preserve the biodiversity, the botanical features, the ontogenetic state, the ecological and phytocenotic structure of the rare endangered species *Rh. rosea* in the highlands of Eastern Kazakhstan were studied.

Results: Ten populations of *Rh. rosea* were identified under various ecological and geomorphological conditions with a detailed description of the structure of the plant community. Systematic analysis of the plant community with *Rh. rosea* shows that the families Poaceae Barnhart, Ranunculaceae Juss., Asteraceae Bercht, J. Presl, Rosaceae Juss. and the leaders in the number of species are Caryophyllaceae Juss., Apiaceae Lindl., Fabaceae Lindl., Polygonaceae Juss. They make up 97 (69%) of the species in the plant community. Ecological analysis data show that the plant community is dominated by psychrophytes (32%), mesophytes (28%), mesopsychrophytes (11%) and mesoxerophytes (7%). Chorological analysis of plant populations with *rh. rosea* indicates that the Asian group (39%), the Eurasian group (30%), and the Holarctic group (20%) are the most widely represented. In *Rh. rosea* populations, it is most often found with *Schulzia crinita*, *Achillea ledebourii*, *Doronicum altaicum*, *Macropodium nivale*, *Hylotelephium telephium*, *Rhodiola algida*, *Carex capillaris*, *C. aterrима*, *C. stenocarpa*, *Euphorbia pilosa*, *Trifolium lupinast*. In the ontogenesis of *Rh. rosea*, all age-related conditions were identified, with the exception of the prussic condition, and the life expectancy is 50-55 years.

Conclusions: The state of *Rh. rosea* populations is assessed as satisfactory, capable of self-sufficiency mainly due to vegetative reproduction. Seed renewal is low as a result of seedling death in the early stages of development due to extreme habitat conditions. In communities with *Rh. rosea*, one- and two-species families predominate, which indicates the complexity of the process of florogenesis in extreme conditions of existence. In general, the distribution of life forms, ecological groups, and species composition of communities with *Rh.* the participation of the rose is natural for extreme conditions of existence.

Background

The study of the ecological and botanical characteristics of natural populations of rare and vulnerable plants remains a priority in the strategy of biodiversity conservation. Currently, many valuable medicinal plants are subjected to spontaneous gathering, as a result of which the number and areas of natural habitats are reduced, the natural balance in communities is disrupted, which leads to population degradation (Cunningham, 2020). This includes *Rh. rosea*, the demand for which has grown significantly throughout the world in recent years, which threatens the extinction of natural populations on a global scale. *Rh. rosea* is listed in the Red Books of Buryatia (Russia), Yakutia (Russia), Tyva (Russia), Mongolia,

Great Britain, Finland, and is protected by the laws of these countries. For example, this plant in Bulgaria is protected by the law on biological diversity. The procedure for the protection and sustainable use of plants is discussed in the Law on Medicinal Plants of this state. In Bulgaria, as in other countries, the amount of natural resources of *Rh. rosea* is gradually decreasing (Tasheva, Kosturkova, 2012).

Individual populations of *Rh. rosea* are included in protected areas in the CIS countries. It is successfully cultivated in botanical gardens and introduction centers of Russia (St. Petersburg, Gorno-Altaysk, Novosibirsk, Irkutsk, etc.) (Moryakina et al., 2008). The regenerative capacity of wild plants is limited due to the very low seed germination rate (5–35%) and the coefficient of vegetative reproduction (Platikanov et al., 2008). In view of the above, the widespread use of natural habitats in many countries has led to the disappearance of the species, which has provoked the adoption of a number of conservation measures: cultivation in appropriate conditions (Matthys et al., 2007), the inclusion of species in the Red Books of Rare and Endangered Plant Species ((WMS)The World Medicines Situation, 2011); protection of populations in specially protected natural areas ((WHO (World Health Organization), 2005).

Rhodiola rosea L., Crassulaceae DC. is psychrophyte with Eurasian arctic alpine disjunctive natural habitat ((POWO)Plants of the World Online, 2021). It is rare species included in the Kazakhstan Red Data Book with status of III class. Threatened species (Kazakhstan Red Data Book. Baitullina, 2014). According to the data of International Union for the Conservation of Nature Resources, the rarity category is Least concern (LC) (Chadburn, 2020). It is guarded in Katon-Karagai State National Natural Park, Markakol and Eastern Altai conservancy area in the studied region. It grows in alpine and subalpine belts, stony tundras, on the rocks and rocky hills, on placers and moist soils along river banks. In Kazakhstan, it is observed in three floristic regions 22. Altai, 23. Tarbagatai, 24. Dzhungarskiy Alatau (Kazakhstan flora, 1957). General area is in the Southern Siberian mountains, on Ural, in transpolar regions of Yakutia, in the highland areas of Eastern Siberia and Far East, on the coasts of White and Barancevo seas, in Mongolia, China, Northern America and Asia Minor (Kazakhstan flora, 1957; Borisova, 1939; Ivanova, 1979; Peshkova, 1994).

The flora of Kazakhstan Altai includes 2,450 species from 693 genera and 131 families, which is 44% of the total number of species of the flora of Kazakhstan (Kotuhov, 2005). The plant resources of Kazakhstan Altai have long attracted the attention of researchers, as they are a source of high-quality raw materials for medicine and industry, as well as the selection of highly productive forage grasses for agriculture and the original forms of ornamental and fruit-berry plants for breeding and gardening (Aidarbayeva et al., 2018).

An important topic to preserve natural environment in which grows *Rh. rosea* is to evaluating the type and flock size of the grazing in order to preserve their natural habitat, using sustainable criteria (Perrino et al., 2020; Buse et al., 2015). Nowadays golden root is classified as rare and endangered species, in many regions - as a protected plant. One reliable way to preserve this plant is to introduce it into culture (Karpukhin et al., 2020). In many countries, sustainable ecological use of natural resources, conservation and conservation of natural areas as a special environmental activity, support of biological and

landscape diversity and improvement of the population of wild species, fauna and mycota of forest areas are regulated (Yaneva et al., 2020). The rare plant of *Rh. rosea* from natural habitats was evaluated as a basis for the development of effective methods of reproduction and for the conservation of rare species, and the effect of seeds of different quality from different habitats on germination was revealed (Bocharov et al., 2017).

Scientists suggest that the protection of the species in situ in nature is insufficient to preserve the gene pool of the *Rh. rosea* population. It seems appropriate to create synthetic ex situ populations and return them to nature (Hou et al., 2011). *Rh. rosea* is an endangered medicinal species with a limited distribution. It is of exceptional importance to the pharmaceutical industry for the prevention and treatment of diseases. Despite the great interest in the golden root and extensive research in the field of phytochemistry, plant biotechnology remained less studied and widely used (Li et al., 2019; Olsson et al., 2009).

Studies of many Russian scientists are devoted to the study of ecological and botanical characteristics, distribution, ontogeny of populations (Sofronov et al., 2016; Valuiskih et al., 2017; Panossian et al., 2010; Yakubov et al., 2019; Shadrin et al., 2020). Relatively fewer ecological-population studies of *Rh. rosea* were carried out in Europe and North America (Olfelt et al., 2014; Aiello et al., 2013), however, the research on genetic biodiversity of populations were well presented (György et al., 2012; György et al., 2013; Soni et al., 2010; Kozyrenko et al., 2018; György et al., 2014).

The study of the ecological and botanical characteristics of natural populations of rare and vulnerable plants remains a priority in the strategy of biodiversity conservation, especially if they are Crop Wild Relatives (Perrino, 2021).

Therefore, purpose of the work is to study the botanical features, ontogenetic state and ecological and phytocenotic structure of rare endangered species *Rh. rosea* on the highlands of East Kazakhstan for the conservation of biodiversity.

Materials And Methods

Kazakhstan Altai is a system of ridges in the southern and southwestern part of Altai, as a mountainous country that stretches from south to north and from west to east for almost 400 km. It is a part of the southwestern periphery of the Altai-Sayan mountain system and with its inherent structure of landscape and high-altitude zones. According to the physical and geographical conditions, the territory of the Kazakhstan Altai is subdivided into three subdistricts which are Southwestern Altai, Southern Altai, Kalbinsk Highlands (Yegorina, 2003).

To identify the phytocenotic features of *Rh. rosea* populations, traditional methods of field geobotanical studies were used using the ecological-physiognomic approach. The ecological-physiognomic types combine plant communities with dominants belonging to one ecobiomorph and ecologically similar groups of species (Bykov, 1970). The research was carried out between 2018–2020 in Southern Altai

(Naryn, Sarymsakty, Southern Altai Tarbagatai, Kurchym ridges) and Western Altai (Ivanov, Ubi, Ulbi, Koksım Linei, Western Listvyaga ridges) of Kazakhstan part. The administratively investigated region belongs to the East Kazakhstan region. Geographic zoning and names of mountain ridges are indicated according to the Physical Map of Kazakhstan.

The rarity category and status of the species are indicated in accordance with the Kazakhstan Red Data Book (Kazakhstan Red Data Book, 2014) and The IUCN Red List of Threatened Species (IUCN, 2020). The analysis of life forms was carried out using the approaches of I.G. Serebryakov (1962) and Raunkiaer C. (1934). In attempt to identify the distribution of the species on the territory of East Kazakhstan, the herbarium materials of the Altai Botanical Gardens (further termed 'Alt.') and Astana Botanical Gardens (further termed 'Ast.') were examined. Besides that, rare herbarium collections stored in the Herbariums of the Institute of Botany and Phytointroduction (AA) were elaborated. The structure of each particular population and ontogenetic structure were studied according to the methods T.A. Rabotnov (1964) and O.V. Smirnova (1976). A.A. Uranov (1969) method were applied to study out the life cycle. The methodological guidelines developed by M.F. Golubev and E.F. Molchanov (1978) were used as a basis for studying ecological, biological characteristics of the species in the real-life field conditions. The ecological analysis of the species was conducted in accordance with the A. V. Kuminova (1960) classification. Nomenclative names of the plants are listed in accordance with POWO (Plants of the World Online, 2021). The analysis of the composition of the flora composition of *Rh. rosea* was carried out in comparison with the Alpine flora of Altai (AFA) (Revushkin, 1988).

To calculate the occurrence of species in the *Rh. rosea*, in each surveyed population, 15 counting plots with an area of 1 m² were laid, all plant species were counted inside the site, a total of 150 plots were taken into account. The obtained values were grouped into five classes of occurrence: I – 0–20%, II – 21–40%, III – 41–60%, IV – 61–80%, V – 81–100%.

The studies were conducted according to the scheme proposed by T.A. Rabotnov (1964) and O.V. Smirnova (1976). The next classification of age groups was used in the description: plantlets (p), juvenile (j), immature (im), virginile (v), young generative (g1), mature generative (g2), old generative (g3), subsenile (old vegetative, ss). "Distribution of *Rh. rosea* in East Kazakhstan" was obtained by ArcMap. The correlation analysis was done by Pearson in the R-studio program.

Results

Distribution of *Rh. rosea* in East Kazakhstan

The study was carried out in the period 2015-2020 on the Ivanovo Ridge by stationary research methods with the laying of monitoring sites in the upper reaches of the Bolshaya Transverochka River (50 ° 19 '13.5" s. w., 83 ° 45 '11.0" w.d.). The studied species are distributed on the ridges of the Kazakhstan Altai and Tarbagatai.

Based on the long-term herbarium collections of the authors of this work stored in Altai Botanical Garden (further termed 'Alt.') and Astana Botanical Garden (further termed 'Ast. '), as well as a result of the revision of the herbarium materials of the Moscow State University (MW) (Seregin, 2020) and the herbarium of the Institute of Botany and Phytointroduction (AA), the distribution of *Rh. rosea* in Eastern Kazakhstan was revealed. In addition the literature data are taken into account (Perrino et al.; Zair et al., 2020; Artemov, 2020; Kotuhov, 2005; Isayev, 1993; Zibzeyev, 2015; Kupriyanov, 2020) the distribution of *Rh. rosea* in the study region. The distribution map of the view is shown in Figure 1.

Specimens examined:— WESTERN ALTAI: was revealed: Ivanovski ridge: vicinity of Ridder mountain, Khorizovka river narrow, 29.VI.1936, Rubam & Mikhailova (AA); near the small liver, between blocks of moraine debris, 15.VI.2015, Kubentayev (Ast.); top of Poperechka river, along the river bank, 03.VII.2012, Kotukhov (Alt.); «Prohodnoj belok», along the damp rocky places, 10.VI.2016, Kubentayev (Ast); vicinity of Rodonovoi river, along the damp rocky places, 10.VI.2015, Kotukhov (Alt.); Ulbi ridge (northern faces of Kreslova mountain, Ridder region, 26.VII.1937, Kuznecov (AA, MW); Lineiski ridge: valley of Chernaya Uba river, south- western slope on the altitude of 1830 m., 03.VII.1998, Kotukhov (Alt.); Koksi ridge: in Latuniha river-valley, 27.VI.2003, Kotukhov (Alt.); in Chernaya Uba river-valley, 03.VI.2003, Kotukhov (Alt.); Ulbi ridge: Bolshoi Turgusun river-valley, 15.VI.2004, Kotukhov (Alt.); top of Tatarka river, 15.VII.2004, Kotukhov (Alt.); Ubi ridge: Belaya Uba river-valley, 12.VI.2006, Kotukhov (Alt.). IN SOUTHERN ALTAI: Chindagatui mountains: Southern Alai ridge, moist meadow in the down part of the slope, 1800m., 27.VII.1986, Ivaschenko & Utebekov (AA); Narym ridge: Koksar mountain, 7.VII.1973, Mikhailov & Stepanova (AA); Southern Altai-Tarbagatai ridge: Burkhat pass, northern slope at the top of the forest, 14.VII.1973, Isayev (AA); left bank of Karakaba river, northern slope, 2100 m., 28. VI.1988, Ivaschenko (AA); vicinity of Chernovoye village, in the upper part of the forest, 15.VI.2016, Kubentayev (Alt.); in the vicinity of the bridge across Karakaba river along the Austria road, damp rocky places, 18.VI.2016, Kubentayev (Alt.); southern-eastwards of Enbek village, at the top of a ridge in the alpine belt, 01.VI.2017, Kotukhov (Alt.); Sarymsakty ridge: Kumshybai, by the stream along the path to the waterfall, damp meadows, 22. VI.1986, Ivaschenko (AA); at the top of Solonechnaya river, 22.VIII.2010, Kubentayev & Zhumagul (Ast.); in the vicinity of Topkain river, alpine meadows, 10.VIII.2020, Kubentayev (Ast.); Western Listvyaga ridge: at the foot of Schebniuha hill, valley of mountain river, 10.VII.2019, Kubentayev (Ast.); Repnoie river head, Kubentayev & Zhumagul, 22.VII.2019; vicinity of Aksharbak village, Katon-Karagai region, Verhkatun riverhead, 22.VII.2020, Kubentayev (Alt.).

"Distribution of *Rh. rosea* in East Kazakhstan " was obtained by ArcMap

Ecological-biological and phytocenotic structure of populations *Rh. rosea*

The study of population of *Rh. rosea* was carried out at 4 loci: Ivanov ridge (4 population); 2) Sarymsakty ridge (2 Population); 3) Southern-Altai Tarbagatai ridge (2 Population); 4) Western Listvyaga ridge (2 Population) belonging to the territory of Kazakhstan Altai (22. Altai), according to the floristic zoning of Kazakhstan (Kazakhstan flora.1957). This species populates on wet moss-covered rocks, rocky hills, near

snowfields, over growing morains, among moss along the river banks, in the upper limit of mossy cedar-larch forests (Fig. 2)

1. Population (*Macropodium nivale*–*Angelica archangelica*–*Rh. rosea*) is timed to the western slopes of shallow ravines of shallowed river beds. Population is studied Burkhat pass, Sarymsakty ridge, (49°07'49.9"N, 86°02'19.8"E) in the altitude of 1950-2050 m. Projective cover (PC) is 55%. Standing grass crop is formed diffusively, along the rock cracks, between the debris of blocks and in degradations where the fertile soil layer accumulates. There are *Coptidium lapponicum*, *Aquilegia glandulosa*, *Sanguisorba alpina*, *Rumex acetosa*, *Bistorta elliptica*, *Trollius altaicus*, *Macropodium nivale*, *Geranium albiflorum* and etc. in the community. The population of *Rh. rosea* as a rule, is represented by all the age states with predominance of generative adult species. The habitat conditions are livable to the development.
2. Population (*Carex stenocarpa*+*C. orbicularis*+*Rh. rosea* +*Dracocephalum grandiflorum*) occurs in well overgrown steep moraine slopes, Sarymsakty ridge, Solonechny river (49°05'34.7"N, 85°29'10.3"E). Moraine hillocks are located on the steep northwestern slopes of the ridges in the altitude of 1900–2100 m above sea level with closely located snowfields. PC is 80-90%. Typical species for these communities are *Festuca kryloviana*, *Allium schoenoprasum*, *Hedysarum neglectum*, *Anemonastrum narcissiflorum*, *Thalictrum alpinum*, *Papaver nudicaule*, *Neogaya simplex*, *Gentiana grandiflora*, *Pedicularis oederi*, *P. amoena*, *P. violascens*, *Oxytropis alpina*, rare enough *Gentiana algida*, *Papaver nudicaule*, *Festuca altaica*. *Betula rotundifolia* should be noted among the shrubs, which forms separate small clumps. Favorable water and temperature conditions, high humus content in the soil determine the lush development of vegetation, which negatively affects the populations of *Rh. rosea* due to its low competitiveness.
3. Population (*Alchemilla gottsteiniana*–*Polygonum ellipticum*+*Rh. rosea*) is timed to smooth slopes of alpine meadows on the alpine meadow soils, Southern Altai Tarbagatai, Karakaby depression, KaraKaba river-valley (49°04'06.8"N, 86°05'14.8"E). Total PC is 85 %. The shrub layer, where *Lonicera altaica*, *Potentilla glabra* is rarely occurred, is poorly expressed, *Spiraea media* shrubs are singly noted. *Koenigia alpina*, *Phleum alpinum*, *Valeriana dubia*, *Rumex acetosa* *Galium boreale*, *Iris ruthenica*, *Dracocephalum grandiflorum*, *Aster alpinus*, *Papaver nudicaule*, *Vicia cracca*, *Sedum hybridum*, *Pedicularis achilleifolia*, *Pachypleurum alpinum*, *Oxytropis alpina*, *Gentiana algida*, *Crepis chrysantha* is often found in the phytocoenosis. The population of *Rh. rosea* in this type undergo degradation. Gradually expanding, meadow vegetation displaces *Rh. rosea* from familiar habitats. Ontogenesis is dominated by generative and senile individuals, seed reproduction is absent.
4. Population (*Rh. rosea* +herbo variae) occupy excessively cold, moderately humid rocky peaks and southwestern slopes of weakly closed pressure moraine ridges in the altitude limit of 2000-2300 m. above sea level, Southern Altai Tarbagatai ridge (49°10'04.4"N, 86°16'07.3" E). PC is 30%. The vegetation cover is poorly developed and relatively poor in terms of species. The most common herbaceous plants are *Carex aterrima*, *C. orbicularis*, *Schulzia crinita*, *Micranthes punctata*, *Papaver croceum*, *Anemonastrum narcissiflorum*, *Salix rectijulis* is relatively common among shrubs. In these population *Rh. rosea* is represented mainly by aging generative and deeply senile individuals.

Analysis behind the developmental state of *Rh. rosea* in the upper limit of its distribution give grounds to consider these habitats as extreme.

5. Population (*Hedysarum neglectum*+*Carex orbicularis*+*C. aterrima*+*Rh. rosea*) occurs in weakly covered moraine ridges, Ivanov ridge, upper parts of Big Poperechka river (50°19'13.5"N, 83°45'11.0"E). They are usually along the northwestern microslopes, on the altitude of 2000-2300. PC is 70%. There are *Rhodiola algida*, *Dryas oxyodonta*, *Bergenia crassifolia*, *Hedysarum neglectum*, *Pedicularis achilleifolia*, *Neogaya simplex*, *Oxytropis alpina*, *Pedicularis amoena*, *P. oederi* and etc. in the community *Hedysarum theinum*, *Saussurea alpina*, *Schulzia crinita*, *Luzula spicata* occurs comparatively rare. Open areas are richly covered by *Polytrichum juniperinum*, *P. alpinum* mosses and species from the genus *Bryo*. Patches of lichens from the genus *Cladonia* are commonly found. *Rh. rosea* in the coating occupies no more than 5-6% of the total amount.
6. Population (*Deschampsia caespitosa* + *Senecio pratensis* + *Rhodiola rosea*) observed on moderately humid stony-mobile fine-gravel slopes of moraine ridges, Ivanov ridge, passing snow-covered mountain peak (50°15'10.3"N, 83°31'31.8"E) (Fig. 1). It is found on the altitude of 1800-1900 m. above sea level. PC is not more than 40%. In this kind of conditions *Rh. rosea* grows far from drains, constantly face the lack of moisture. The vegetation cover is not poorly expressed, it is usually found *Carex pediformis* var. *macroura*, *C. capillaries*, *Festuca borissii*, *Helictotrichon altaicum*, *Lagotis globosa*, *Callianthemum alatavicum*, *Saussurea alpina*, *Dracocephalum grandiflorum* here in the community. *Dryas oxyodonta*, *Thalictrum alpinum*, *Gentiana algida*, *Eritrichium villosum*, *Allium schoenoprasum*, *Pachypleurum alpinum*, *Crepis chrysantha* are found very rarely. Plants do not form dense tangled vegetation. They are found in separate groups or single individuals. *Betula rotundifolia*, *Cotoneaster uniflorus* are rare among the shrubs, and *Juniperus sibirica* is individually found.
7. Population (*Rh. rosea* – *Trisetum altaicum* – *Deschampsia caespitosa*) occupy cold waterlogged coastal lake habitats, Ivanov ridge, near Maloye lake (50°18'36.9"N, 83°44'44.7"E), on the altitude of 2000-2100 v. above sea level. population data is timed to northeastern the shores of permanent dammed lakes in the close proximity of the water. PC is 15-25 %. Tangles of *Rh. rosea* occupy a narrow coastal strip from the very edge of the water no more than 1.5–2 m wide. The vegetation cover is represented by separate plants or small groups of the communities, where *Carex aterrima*, *Deschampsia caespitosa*, *Festuca borissii*, *Trisetum altaicum*, *Phleum alpinum*, *Swertia obtuse*, *Primula nivalis*, *Rhodiola algida*, *Sanguisorba alpine*, *Caltha palustris*, *Bistorta vivipara*, *Allium schoenoprasum*, *Gentiana algida* are often found. *Salix lanata* and *S. rectijulis* are relatively rare. In the herbage, *Rh. rosea* is found relatively abundantly, the population is full-lived.
8. Population (*Salix lanata* – *Betula rotundifolia* – *Rh. rosea*) occupies moderately humid bushy tundra habitats, Ivanov ridge (50°19'36.4"N, 83°48'17.8"E). The communities with the participation of *Rh. rosea* are timed to northwestern steep slopes on the altitude limit of 2100 – 2200 m above sea level. PC is 50-60%. The herbage is less abundant. *Carex aterrima*, *Trollius altaicus*, *Pedicularis oederi*, *Thalictrum alpinum*, *Macropodium nivale*, *Geranium albiflorum*, *Gagea serotina* are found in phytocenosis. *Betula rotundifolia* tangles reach a height of 35-40 m, rarely 50 m in the

communities. The population of *Rh. rosea* in this kind of population is believed extreme. Gradually expanding, tangles of birches crowd them out from their habitats.

9. Population (*Rh. rosea* + *Achillea ledebourii*– *Sanguisorba alpine*) occupies coastal and excessive wet meadows, constant verges of the streams, cedar larch wood meadows on the altitude of 1700-1900 m. Western Listvyaga, upper part of Repnaya river (49°21'06.0"N, 85°41'54.8"E). Excessive moisture and light shading throughout the growing season create unfavorable conditions for the development of *Rh. rosea*. The vegetation cover is well formed, PC is 65–80%. *Alchemilla altaica*, *Primula nivalis*, *Carex curaica*, *C. aterrima* are often found in the community, while *Carex orbicularis*, *Cerastium davuricum*, *Bistorta vivipara*, *Trollius altaicus*, *Deschampsia cespitosa*, *Allium schoenoprasum*, *Myosotis scorpioides*, *Veratrum lobelianum*, *Delphinium elatum*, *Caltha palustris* are rarely found. *Rh. rosea* is timed to areas in the form of narrow ribbons of 1.5 – 2 m width along the coasts. There are no shrubs. In rare cases, *Lonicera altaica* is noted along the coastline. *Rh. rosea* forms small clumps on areas bare from grass. Generative individuals of *Rh. rosea* predominate in the population of this type.
10. Population (*Rh. rosea* – *Dichodon cerastoides*– *Allium schoenoprasum*) occupy the shores of mountains streams, wells, drains which bear a temporary nature by the process of melting snow patches and which dry starting from the mid July, Western Listvyaga ridge, in the vicinity of Schebnuiha mountain (49°21'54.0"N, 85°44'58.9"E), on the altitude limit of 2000-2200 m. *Rh. rosea* plants on the boulders covered by the thick moss cover. The vegetation cover in the phytocenosis is poorly expressed. PC is 30-40%. The following species are found in the community: *Primula nivalis*, *Carex orbicularis*, *C. aterrima*, *Bistorta vivipara*, *Pedicularis oederi*, *Deschampsia cespitosa*, *Micranthes punctata*, *Macropodium nivale*, *Sanguisorba alpina*, *Lagotis globosa*, *Gentiana algida*. Populations of *Rh. rosea* are of normal type, young, full-lived. Habitat conditions can be considered optimal.

Table 1 shows the morphometric parameters of *Rh. rosea* in the surveyed population of Kazakhstan Altai. According to the data obtained, it was found that the highest number of individuals per 1 m² was observed in P10 (0.75), P7 (0.68) and P1 (0.56), a relatively low number per unit area was noted in P8 (0.18), P6 (0.21) and in P3 (0.23). For *Rh. rosea*, in populations with a high number of individuals per unit area, undersized, multi-shoot shrubs with large flowers are characteristic. In the population with a low abundance of *Rhodiola* per unit area, tall individuals are observed, with loose, low-shoot bushes and relatively small inflorescences. Undersized, multi-stem structure with large flowers prevail per square for *Rh. rosea* in populations with a high number of species. Tall individuals, with crumbly, low-running bushes and relatively small inflorescences prevail in the population with a low number of *Rh. rosea* per square. This pattern is explained by the habitat conditions. As a rule, species of *Rh. rosea* are relatively tall (45-50 cm), have crumbly low-running bushes (6-10 pcs) and small inflorescences (3-4.5 cm) in the forest belt and in tall grass communities. In open, poorly populated areas, and along the valleys of mountain streams, individuals are significantly undersized (20–25 cm), but have a multi-stem structure (30–50 pcs) and large flowers (5.2–6 cm) (Fig. 3). The correlation analysis of morphological and quantitative indicators of *Rh. rosea* between the studied populations is shown in Fig. 4.

Table 1. Quantitative and morphological indicators of *Rh. rosea*

Quantative and morphological indicators		Number of adult specimens per 1m ²	Height of generative species at the time of flowering (cm)	The number of sprouts per a specimens (pcs)	Inflorescence diameter (cm)
P 1	M	0,56	24,42	21,41	5,25
	SD	0,03	1,62	2,01	0,31
P 2	M	0,32	48,33	15,22	4,20
	SD	0,01	1,28	1,61	0,26
P 3	M	0,23	35,52	6,91	4,35
	SD	0,01	2,12	0,65	0,16
P 4	M	0,28	26,66	20,32	3,63
	SD	0,01	2,91	1,71	0,18
P 5	M	0,42	47,22	28,31	5,39
	SD	0,04	1,81	2,16	0,27
P 6	M	0.21	38.30	12.27	4,23
	SD	0.01	1.21	1.63	0,15
P 7	M	0,68	31,19	36,55	5,46
	SD	0,02	1,72	1,11	0,31
P 8	M	0,18	49,29	8,12	3,81
	SD	0,01	2,33	0,69	0,25
P 9	M	0,33	45,61	6,06	3,22
	SD	0,03	2,72	0,31	0,13
P 10	M	0,75	32,30	37,33	4,81
	SD	0,03	1,44	2,82	0,33

Ontogenetic state *Rh. rosea*

The ontogenetic state of *Rh. rosea* was studied on Ivanov ridge, in the upper parts of Big Poperechka river (50°19'13.5"N, 83°45'11.0"E). *Rh. rosea* begins to vegetate under a cover of snow starting from mid-May to mid-June in the studied area and when the snow melts, it begins to grow rapidly. It blooms from mid-June to late July. The fruits ripen from August to September. It should be noted that the seasonal rhythm of the species development depends on the height of the location of the population. The species begins

to grow from mid-May in the upper limit of the green belt at an altitude of 1700–1900 m. *Rh. rosea* grows in the second half of June in the alpine belt at an altitude of 2200-2400 m. On average, the growing season lasts 4 months.

The species in the surveyed area reproduces predominantly in a vegetative way due to the division of rhizomes and spread by melt water during the period of abundant snow melting, but in some places seed renewal is noted. Seeds are small, oblong. The seeds shape is curved-pin-shaped. The seeds surface is bare, longitudinally wrinkled. The seed scar is small, slightly protruding, basal, rounded. Seed color is from light brown to hazel. The length is $2,13 \pm 0,16$ mm, $Cv=15.7\%$; min-max – 1,65 – 2,78 mm, the width is 0,48 – 0,81 mm ($0,59 \pm 0,07$ mm, $Cv=17.5\%$). The weight of 1000 seeds is 0,208 – 0,239 g. Once in the soil, ripen seeds undergo natural stratification over the next 7-8 months. The laboratory germination of *Rh. rosea* seeds in Petri dish at 18°C in three replications has shown 51%.

Plantlets (Fig.5. (p)) start appearing at the end of May and beginning of June. Emergence of seedling is above-ground. Seed leaf is light green, bare, succulent $3,2 \pm 0,09$ mm long, $1,8 \pm 0,06$ mm wide. The plates are oval-ovoid, on short petioles up to 2.8 mm long. Rounded at the apex, sharply tapered at the base turning into a short petiole. The hypocotyl is 3.2 ± 0.07 mm long, up to 1.1 ± 0.03 mm thick, pale green, the basal part is thickened, sharply passes into the embryonic (primary) root. The main root up reaches 2.3 ± 0.08 cm long by the time the cotyledons dry up with a significant number of lateral shortened suction roots. Cotyledons persist until mid or late July. In 2-3 months after germination of the seed, this age condition ends.

At the end of July and beginning of August the species turns into juvenile state (Fig.5(j)). Plants in this phase are characterized by the formation of a rosette of 2.6 ± 0.04 cotyledonous leaves, the presence of a crown bud and 1-2 axillary buds of an open type. The part of the growth sprout (rhizome) does not die off after the end of the vegetation season, but becomes perennial, from which the rhizome is subsequently formed. The seedlings end the juvenile phase at the age of 2-3 years and less often.

Immature phase (Fig.5((im))) is characterized by the growth of vegetative stems of normal type in the structure of medial sprout. The medial sprout of $7,2 \pm 0,12$ cm height has $6,9 \pm 0,21$ pieces of natural leaves. The leaves are set by turn, the leaf blade is oblong-ellipsoid at the base and smoothly tapers into a short petiole. The crown and lateral buds of the growing sprout are of a closed type. The growth part of the rhizome is 2.4 ± 0.2 cm in length and 0.6 ± 0.003 cm in thickness. Rhizome branching is observed. The root system is well developed in the horizontal projection 2.8 ± 0.08 cm and in the vertical projection 12.1 ± 1.56 cm (deepened). In the primordial state, plants are on average 2 vegetation seasons. In the future, the plants move to the next age state.

Virginal phase might be seen for 5-7 year and is characterized by the beginning of branching of the medial sprout of the rhizome with the development of a significant number of lateral sprouts of the first order with the development of stems on them. The plants in this age state are $14 \pm 1,31$ cm in height. The rhizome has $3,6 \pm 0,07$ pieces of stems of the first order. The medial sprout of the rhizome and some lateral sprouts are 6.2 ± 0.06 cm long at the base and 0.83 ± 1.2 cm across. The root system is well

developed, 10.2 ± 1.8 cm in horizontal projection and 16 ± 2.2 cm in vertical projection. The primary root is about 1.8 ± 0.06 cm in thickness. The buds of the renewal of the medial and lateral sprouts are large, of a closed type.

The plants come into the phase of young generative species (Fig.5(g1)) at the age of 8-11 years. Generative stems are formed in medial sprout. Young plants usually generate $2,8 \pm 0,06$ pieces of generative stems with a depleted inflorescence of $1,8 \pm 0,02$ flowers and $8,2 \pm 2,6$ vegetative stems in their first two years. Plants at the age of 8-10, more often 12 years old begin to form generative stems on the sprouts of the rhizome of the first order. The rhizome of the horizontal projection has a thickness of 3.2 ± 0.9 cm and a length of 16.3 ± 0.8 cm. The number of flowers in an inflorescence is 6.3 ± 1.8 pieces, a diameter of 4.8 ± 0.35 cm. The height of the plant is 30 ± 1.8 cm. In this age state, stems begin to form on the sprouts of second-order rhizomes. This age-related condition ends by 18-22 years.

The mature generative individuals (Fig. 5(g2)) include plants aged 22-30 years, characterized by a powerful development of 43 ± 2.1 cm in height. There is an intensive development of generative stems on the medial sprout of the rhizome and sprouts of the first and second orders. Such individuals have 35 ± 3.6 pcs of generative and 42 ± 2.8 pcs of vegetative stems. Inflorescence with 10.6 ± 1.7 flowers, 5.2 ± 0.35 cm in diameter. Abundant flowering and fruiting. Particulation and clone formation are observed.

The plants come into the phase of old generative species at the age of 30-40 years. There is a noticeable predominance of vegetative stems up to 68 ± 3.9 pcs and the formation of a significant number of weakened generative stems 52 ± 2.8 pcs in this age state. There are usually 6.2 ± 0.12 flowers, 3.8 ± 0.35 cm in diameter in the inflorescence. The beginning of the rhizome sprouts death and the formation of extensive foci of the main root necrosis and medial sprout of the rhizome are observed. Also, mass dying of rhizomes sprouts of the first order is typical in this age state.

Senile species (Fig. 5 (ss)) are very rare. It is pretty hard to define the age of this species. According to our data, it comes into this phase at the age of 50-55 years. In this state, extensive foci of necrosis appear almost along the entire length of the main rhizome and its disintegration into separate girders. There are frequent cases of dying of the adventitious roots of the first-order rhizome sprouts. The bushes easily break up into 3-6 clones, form new plants and spread over the population area.

Analysis composition of the flora of communities with *Rh. rosea* involvement

The spectra analysis of geographic elements of floras of various ranks, including floras of plant communities in the volume of specified classification units (composition of the floras) is one of the main tools of comparative floristry. Composition of the flora is a set of plant species which form communities of any rank and any type of vegetation. From this point of view, the composition of the flora represents the unification of historically and coenotically homogeneous groups of species within the syntaxon, which makes them the most important indicator of the vegetation cover from the level of a particular phytocenosis to altitudinal-belt units. This reveals the most important meeting points between floristry and geobotany.

As a result of data processing of field studies and herbarium collections, it was found that the composition of the flora of communities with the participation of *Rhodiola rosea* includes 140 species belonging to 39 families and 104 genera, which is 14% of the Altai highland flora (AHF), where 996 species of vascular plants from 325 genera and 80 families are registered (Table 2). Herbarium collections are kept in the herbarium of the Astana Botanical Garden and the Altai Botanical Garden.

Table 2. Floristic composition of *Rh. rosea* composition of the flora of Kazakhstan Altai

Nº	The species name	1*	2	3	4	5
<i>Amaryllidaceae</i>						
1.	<i>Allium schoenoprasum</i> L.	III	C	Bbp	HP	euras.
2.	<i>Allium flavidum</i> Ledeb.	I	C	Bbp	MP	as.
<i>Apiaceae</i>						
3.	<i>Neogaya simplex</i> (L.) Meisn.	II	HC	Tp	P	euras.
4.	<i>Angelica archangelica</i> L.	III	HC	Tp	M	as.
5.	<i>Angelica decurrens</i> (Ledeb.) B.Fedtsch.	II	HC	Tp	M	as.
6.	<i>Bupleurum multinerve</i> DC.	II	HC	Tp	MP	as.
7.	<i>Sajanella monstrosa</i> (Stephan ex Schult.) Soják	III	HC	Tp	P	as.
8.	<i>Schulzia crinita</i> (Pall.) Spreng.	IV	HC	Tp	P	as.
<i>Asteraceae</i>						
9.	<i>Aster alpinus</i> L.	II	HC	Tp	X	holarc.
10.	<i>Achillea millefolium</i> L.	II	HC	Lrp	M	holarc.
11.	<i>Saussurea alpina</i> (L.) DC.	II	HC	Lrp	P	holarc.
12.	<i>Senecio nemorensis</i> L.	I	HC	Brp	M	euras.
13.	<i>Solidago virgaurea</i> L.	III	HC	Brp	M	euras.
14.	<i>Hieracium virosum</i> Pall.	II	HC	Tp	MX	euras.
15.	<i>Crepis chrysantha</i> (Ledeb.) Turcz.	I	HC	Srp	P	euras.
16.	<i>Saussurea latifolia</i> Ledeb.	II	HC	Lrp	M	as.
17.	<i>Achillea ledebourii</i> Heimerl	IV	HC	Brp	M	as.
18.	<i>Frolovia frolovii</i> (Ledeb.) Raab-Straube	II	HC	Tp	MP	as.
19.	<i>Leuzea carthamoides</i> (Willd.) DC.	II	HC	Tp	MP	as.
20.	<i>Doronicum altaicum</i> Pall.	IV	HC	Tp	P	as.
<i>Berberidaceae</i>						
21.	<i>Berberis sibirica</i> Pall.	I	NF	S	MPt	cent.as
<i>Betulaceae</i>						
22.	<i>Betula glandulosa</i> Michx. (= <i>B. rotundifolia</i> Spach)	III	NF	S	P	euras.
<i>Boraginaceae</i>						

23.	<i>Myosotis scorpioides</i> L.	II	HC	Brp	H	holarc.
24.	<i>Myosotis sylvatica</i> Ehrh. ex Hoffm.	I	HC	Brp	M	euras.
25.	<i>Eritrichium villosum</i> (Ledeb.) Bunge	I	HC	Tp	P	euras.
<i>Brassicaceae</i>						
26.	<i>Cardamine macrophylla</i> Willd.	II	C	Lrp	HP	as.
27.	<i>Macropodium nivale</i> (Pall.) W.T.Aiton	IV	HC	Tp	P	as.
<i>Campanulaceae</i>						
28.	<i>Campanula cervicaria</i> L.	I	HC	Tp	M	euras.
<i>Caprifoliaceae</i>						
29.	<i>Patrinia sibirica</i> (L.) Juss.	II	HC	Tp	XPt	as.
30.	<i>Valeriana dubia</i> Bunge	I	C	Brp	MX	as.
31.	<i>Lonicera caerulea</i> subsp. <i>altaica</i> (Pall.) Gladkova	II	MF	S	MP	as.
<i>Caryophyllaceae</i>						
32.	<i>Dichodon cerastoides</i> (L.) Rchb.	I	H	Srp	P	holarc.
33.	<i>Cherleria biflora</i> (L.) A.J.Moore & Dillenb.	I	H	Tp	P	holarc.
34.	<i>Sabulina verna</i> (L.) Rchb.	II	HC	Tp	P	holarc.
35.	<i>Sagina saginoides</i> (L.) H.Karst.	II	H	Tp	P	holarc.
36.	<i>Dianthus superbus</i> L.	II	HC	Lrp	M	euras.
37.	<i>Cerastium davuricum</i> Fisch. ex Spreng.	III	HC	Tp	HP	as.
38.	<i>Silene bungei</i> Bocquet	I	HC	Tp	P	as.
<i>Crassulaceae</i>						
39.	<i>Hylotelephium telephium</i> (L.) H.Ohba	IV	HC	Brp	M	euras.
40.	<i>Phedimus hybridus</i> (L.) Hart	III	H	Srp	XPt	as.
41.	<i>Hylotelephium ewersii</i> (Ledeb.) H.Ohba	II	H	Brp	MPt	as.
42.	<i>Rhodiola algida</i> (Ledeb.) Fisch. & C.A.Mey.	IV	H	Tp	P	Alt.
<i>Cupressaceae</i>						
43.	<i>Juniperus communis</i> var. <i>saxatilis</i> Pall. (= <i>J. sibirica</i> Burgsd.)	II	NF	S	MP	euras.
<i>Cyperaceae</i>						

44.	<i>Eriophorum angustifolium</i> Honck.	II	HC	Lrp	HP	holarc.
45.	<i>Carex capillaris</i> L.	V	HC	HS	H	euras.
46.	<i>Carex aterrima</i> Hoppe	IV	HC	Brp	HP	euras.
47.	<i>Carex pediformis</i> var. <i>macroura</i> (Meinsh.) Kük.	II	HC	Srp	MX	euras.
48.	<i>Carex curaica</i> Kunth	I	HC	Brp	H	as.
49.	<i>Carex stenocarpa</i> Turcz. ex V.I.Krecz.	IV	HC	Srp	P	as.
50.	<i>Carex altaica</i> (Gorodkov) V.I.Krecz.	I	C	Lrp	HP	Alt.
<i>Ericaceae</i>						
51.	<i>Vaccinium myrtillus</i> L.	II	H	Ds	MP	holarc.
<i>Euphorbiaceae</i>						
52.	<i>Euphorbia pilosa</i> L.	IV	HC	Tp	XPt	tur.
<i>Fabaceae</i>						
53.	<i>Hedysarum neglectum</i> Ledeb. (= <i>Hedysarum austrosibiricum</i> B.Fedtsch.)	III	HC	Tp	M	euras.
54.	<i>Oxytropis purpurea</i> (Bald.) Markgr.	II	HC	Tp	M	euras.
55.	<i>Trifolium lupinaster</i> L.	IV	HC	Srp	MX	euras.
56.	<i>Hedysarum theinum</i> Krasnob.	III	HC	Tp	MP	as.
57.	<i>Thermopsis alpina</i> (Pall.) Ledeb.	II	HC	Lrp	P	as.
58.	<i>Oxytropis alpina</i> Bunge	III	HC	Tp	P	Alt.
<i>Gentianaceae</i>						
59.	<i>Swertia obtusa</i> Ledeb.	III	HC	Lrp	M	as.
60.	<i>Gentiana algida</i> Pall.	II	HC	Brp	P	as.
61.	<i>Gentiana grandiflora</i> Laxm.	I	H	Tp	P	as.
<i>Geraniaceae</i>						
62.	<i>Geranium albiflorum</i> Ledeb.	II	HC	Brp	M	as.
<i>Juncaceae</i>						
63.	<i>Luzula spicata</i> (L.) DC.	I	HC	Brp	P	holarc.
<i>Lamiaceae</i>						
64.	<i>Dracocephalum ruyschiana</i> L.	II	C	Srp	M	euras.

65.	<i>Dracocephalum peregrinum</i> L.	I	HC	Tp	XPt	as.
66.	<i>Dracocephalum grandiflorum</i> L.	III	HC	Srp	MP	as.
<i>Liliaceae</i>						
67.	<i>Gagea serotina</i> (L.) Ker Gawl. (= <i>Lloydia serotina</i> (L.) Rchb.)	II	C	Bp	P	holarc.
<i>Lycopodiaceae</i>						
68.	<i>Diphasiastrum alpinum</i> (L.) Holub	II	H	Cm	P	holarc.
<i>Melanthiaceae</i>						
69.	<i>Veratrum lobelianum</i> Bernh.	III	HC	Brp	M	as.
<i>Montiaceae</i>						
70.	<i>Claytonia joanneana</i> Schult.	I	HC	Tp	P	as.
<i>Onagraceae</i>						
71.	<i>Epilobium palustre</i> L.	II	HC	Srp	HP	holarc.
72.	<i>Epilobium angustifolium</i> L.	I	HC	Tp	M	holarc.
<i>Orobanchaceae</i>						
73.	<i>Pedicularis oederi</i> Vahl	III	HC	Tp	P	holarc.
74.	<i>Pedicularis violascens</i> Schrenk	I	HC	Tp	XPt	as.
75.	<i>Pedicularis amoena</i> Adams ex Steven	II	HC	Tp	P	as.
76.	<i>Pedicularis achilleifolia</i> Stephan ex Willd.	I	HC	Tp	XPt	as.
<i>Papaveraceae</i>						
77.	<i>Papaver nudicaule</i> L.	III	HC	Tp	MP	as.
78.	<i>Papaver croceum</i> Ledeb.	I	HC	Tp	P	as.
<i>Pinaceae</i>						
79.	<i>Abies sibirica</i> Ledeb.	I	MF	T	M	euras.
80.	<i>Larix sibirica</i> Ledeb.	I	MF	T	M	euras.
81.	<i>Picea obovata</i> Ledeb.	I	MF	T	M	euras.
82.	<i>Pinus sibirica</i> Du Tour	I	MF	T	M	euras.
<i>Plantaginaceae</i>						
83.	<i>Veronica densiflora</i> Ledeb.	I	HC	Lrp	P	as.
<i>Poaceae</i>						

84.	<i>Deschampsia cespitosa</i> (L.) P.Beauv.	IV	HC	Brp	H	cosm.
85.	<i>Anthoxanthum monticola</i> (Bigelow) Veldkamp	I	HC	Srp	M	cosm.
86.	<i>Festuca rubra</i> L.	III	HC	Brp	HP	holarc.
87.	<i>Poa alpigena</i> Lindm.	II	C	Lrp	M	holarc.
88.	<i>Festuca borissii</i> Reverd.	IV	HC	Brp	MP	holarc.
89.	<i>Calamagrostis purpurea</i> (Trin.) Trin.	II	HC	Lrp	H	euras.
90.	<i>Elymus repens</i> (L.) Gould	II	C	Lrp	M	euras.
91.	<i>Alopecurus pratensis</i> L.	II	C	Srp	M	euras.
92.	<i>Dactylis glomerata</i> L.	III	HC	Brp	M	euras.
93.	<i>Helictochloa hookeri</i> (Scribn.) Romero Zarco	II	HC	Brp	MX	euras.
94.	<i>Phleum alpinum</i> L.	II	HC	Brp	P	euras.
95.	<i>Poa sibirica</i> Roshev.	I	HC	Brp	MP	as.
96.	<i>Paracolpodium altaicum</i> (Trin.) Tzvelev	I	HC	Lrp	P	as.
97.	<i>Trisetum altaicum</i> Roshev.	II	HC	Brp	P	as.
98.	<i>Festuca kryloviana</i> Reverd.	IV	HC	Brp	P	as.
99.	<i>Poa attenuata</i> Trin.	III	HC	Brp	MX	Alt.
100.	<i>Koeleria altaica</i> (Domin) Krylov	I	HC	Brp	P	Alt.
<i>Polygonaceae</i>						
101.	<i>Bistorta vivipara</i> (L.) Delarbre	III	HC	Brp	HP	holarc.
102.	<i>Oxyria digyna</i> (L.) Hill	II	HC	Lrp	MPt	holarc.
103.	<i>Koenigia alpina</i> (All.) T.M.Schust. & Reveal	II	HC	Tp	M	euras.
104.	<i>Rumex acetosa</i> L.	III	HC	Tp	M	euras.
105.	<i>Rumex scutatus</i> L.	II	HC	Tp	M	euras.
106.	<i>Bistorta elliptica</i> (Willd. ex Spreng.) V.V.Petrovsky, D.F.Murray & Elven	III	HC	Brp	P	euras.
<i>Primulaceae</i>						
107.	<i>Primula nivalis</i> Pall.	I	HC	Brp	HP	as.

<i>Ranunculaceae</i>						
108.	<i>Ranunculus lapponicus</i> L.	II	HC	Lrp	H	holarc.
109.	<i>Caltha palustris</i> L.	III	HC	Brp	H	holarc.
110.	<i>Thalictrum alpinum</i> L.	I	HC	Srp	P	holarc.
111.	<i>Delphinium elatum</i> L.	IV	HC	Srp	M	euras.
112.	<i>Thalictrum flavum</i> L.	II	HC	Brp	M	euras.
113.	<i>Aconitum septentrionale</i> Koelle	III	HC	Tp	M	euras.
114.	<i>Trollius altaicus</i> C.A.Mey.	II	HC	Srp	M	as.
115.	<i>Anemonastrum narcissiflorum</i> (L.) Holub	II	HC	Srp	MX	as.
116.	<i>Aquilegia flabellata</i> Siebold & Zucc.	IV	HC	Srp	MX	as.
117.	<i>Callianthemum alatavicum</i> Freyn	II	HC	Srp	P	as.
118.	<i>Trollius lilacinus</i> Bunge	I	HC	Brp	P	as.
119.	<i>Aconitum apetalum</i> (Huth) B.Fedtsch.	III	HC	Brp	MP	Alt.
120.	<i>Aconitum glandulosum</i> Rapaics	II	HC	Bbp	MP	Alt.
121.	<i>Ranunculus altaicus</i> Laxm.	IV	HC	Brp	P	Alt.
<i>Rosaceae</i>						
122.	<i>Dasiphora fruticosa</i> (L.) Rydb.	II	NF	S	M	holarc.
123.	<i>Spiraea media</i> Schmidt	II	NF	S	M	euras.
124.	<i>Alchemilla altaica</i> Juz.	IV	HC	Srp	M	euras.
125.	<i>Cotoneaster uniflorus</i> Bunge	II	NF	S	P	euras.

126.	<i>Sibbaldia procumbens</i> L.	III	H	Lrp	P	as.
127.	<i>Dasiphora glabrata</i> (Willd. ex Schltl.) Soják	II	NF	S	P	as.
128.	<i>Dryas oxyodonta</i> Juz.	III	H	Ds	P	as.
129.	<i>Sanguisorba alpina</i> Bunge	III	HC	Tp	P	as.
130.	<i>Sibiraea laevigata</i> (L.) Maxim.	II	NF	S	MX	Alt.
<i>Rubiaceae</i>						
131.	<i>Galium boreale</i> L.	II	HC	Lrp	M	holarc.
<i>Salicaceae</i>						
132.	<i>Salix lanata</i> L.	II	NF	S	P	holarc.
133.	<i>Salix turczaninowii</i> (Laksch.)	II	NF	Ds	P	euras.
134.	<i>Salix rectijulis</i> Ledeb. ex Trautv.	II	NF	S	P	as.
<i>Saxifragaceae</i>						
135.	<i>Saxifraga sibirica</i> L.	I	HC	Brp	HP	as.
136.	<i>Micranthes punctata</i> (L.) Losinsk.	II	HC	Tp	HP	as.
137.	<i>Bergenia crassifolia</i> (L.) Fritsch	II	HC	Lrp	MPt	as.
<i>Urticaceae</i>						
138.	<i>Urtica dioica</i> L.	I	HC	Lrp	M	euras.
<i>Violaceae</i>						
139.	<i>Viola biflora</i> L.	II	HC	Srp	MP	holarc.
140.	<i>Viola altaica</i> Ker Gawl.	III	HC	Tp	P	as.

*1 – Occurrence of species: I – 0–20%, II – 21–40%, III – 41–60%, IV – 61–80%, V – 81–100%.

2 – The life forms are given (Raunkiaer): Meso phanerophytes – MF, Nano phanerophytes – NF, Hamefites-H, Hemicryptophytes- HC, Cryptophytes – C.

3 – The life forms are given (Serebryakov): T – tree; S – shrub; Hs – half-shrub; Ds – dwarfshrub; Lrp – long rhizomatous plant; Srp – short rhizomatous plants; Bbp – bulbotuberiferous plants; Bp – bulbous plants; Tp – taproot plants; Brp – brushy root plants; Tsp – tussock plants; Cm – club-moss.

4 – Ecological groups of plants in relation to the temperature, moisture and stoniness of the substrate: H - hygrophytes, HP - hygropsychophytes, GM - hygromesophytes, M - mesophytes, MX - mesoxerophytes, MP - mesopsychophytes, X - xerophytes, XPt - xeropetrophyte, P - psychophytes, MPt - mesopetrophytes.

5 – The groups of areas are listed: cosm. - cosmopolitan; holarc. - Holarctic; euras. - Eurasian; as. - Asian; tur. - Turanian; Mtr - Mediterranean; Alt - Altai (endemics of the Altai-Sayan botanical-geographical province).

Discussion

The systematic analysis of composition of the flora composition of *Rh. rosea* showed that leading families in terms of the species quantities are *Poaceae* Barnhart (12%), *Ranunculaceae* Juss. (10%), *Asteraceae* Bercht. & J.Presl (9%), *Rosaceae* Juss.(7%), *Caryophyllaceae* Juss.(5%), *Apiaceae* Lindl. (4%), *Fabaceae* Lindl. (4%) and *Polygonaceae* Juss. (4%) (Fig. 9). They account for 77 (55%) species of the composition of the flora composition, which is typical for AHF (Revushkin, 1988).

There are most common 17 species in the composition of the flora of *Rh. rosea* (occurrence IV–V): *Schulzia crinita*, *Achillea ledebourii*, *Doronicum altaicum*, *Macropodium nivale*, *Hylotelephium telephium*, *Rhodiola algida*, *Carex capillaris*, *C. aterrima*, *C. stenocarpa*, *Euphorbia pilosa*, *Trifolium lupinaster*, *Deschampsia cespitosa*, *Festuca borissii*, *F. kryloviana*, *Delphinium elatum*, *Aquilegia flabellata*, *Ranunculus altaicus*, *Alchemilla altaica*. 35 species are rather rare (occurrence I). Most of the species in the composition of the flora are found from 21 to 40% (II) – 59 species and from 41 to 60% (III) – 28 species (Fig. 7).

The composition of the most 10 families in terms of their quantities is almost identical to the composition of leading families of AHF. However, their arrangement in descending order is somewhat different, which is due to the allocation of *Rh. rosea* to the redivided ecological groups. Communities with *Rh. rosea* are dominated by single and two species families, which characterizes the AHF flora (Sofronov R.R.et.al. 2016), the Western Sayan (Kamelin R.V.2016)and the arctic floras which develop in extreme habitat conditions and indicates the complicity of the flora genesis process (Sofronov R.R.et.al. 2016). The analysis of gender spectrum accords well with the composition of the AHF leading genera (Revushkin, 1988), where *Carex* L. (6), *Aconitum* L. (3), *Dracocephalum* L.(3), *Festuca* L. (3), *Pedicularis* L. (3), *Poa* L. (3), *Salix* L. (3) genera prevail.

The lifespan of species in the composition of the flora *Rh. rosea* is represented only by perennials. The analysis of life forms showed that tap root plants (30%), brushy root plants (34%), short rhizomatous plants (14%), long rhizomatous plants (14%), shrubs (7%) prevail in communities with the participation of *Rh. rosea* (Fig. 8). In general, such a distribution of life forms is natural for extreme conditions of existence.

According to the results of the studies, the distribution of the species is observed in the South-Western and Southern Altai of the studied region. We have not confirmed the growth of the species on the Kalbinsky ridge.

Revushkin A.S. (1988) considers, that it is enough to allocate the plants groups for the ecological analysis of highlands due to their humidity and substrate nature, not taking into account the temperature, the salinity and the soil fertility. However, we consider that the exact classification of ecological groups presented by Kuminova A.V. is (Kuminova, 1960) pretty much applicable for the highland flora analysis and the temperature regime is the crucial feature of the highlands. Despite that, we agree that it is inappropriately to allocate groups due to their salinity and soil fertility. Having used this classification, the composition of the flora composition of *Rh. rosea* was studied. The data showed that the composition of the flora is dominated by psychrophytes (32%), mesophytes (28%), mesopsychrophytes (11%) and mesoxerophytes (7%). These groups account for 109 (78%) species of the total composition of species of *Rh. rosea* composition of the flora (Fig. 9).

The chorological analysis of the composition of the flora composition of *Rh. rosea* shows that the Asian group (39%), the Eurasian group (30%), and the Holarctic (20%) are most abundantly represented. The percentage of chorological groups differs somewhat from the AHF, however, the leading groups of habitats nevertheless converge. It should be noted that a significant excess of the Eurasian group content in *Rh. rosea* composition of the flora (30%) compared to the AHF (14.4%), and the participation of Asian species is oppositely lower (39%) than the AHF (62%). (Fig. 10).

Analysis of life forms by Raunkiaer (1934) showed that in communities with *Rh. rosea*, the vast majority of species are Hemicryptophytes (74%), not a large number of species are represented Mesophanerophytes (7%), Nanophanerophytes (8%), Hamerophytes (7%), Cryptophytes account for 4% of the species of cenoflora (Fig. 11).

In the studies of Vedernikova O. P. and Nikandrova L. M. (Vedernikova et al., 2000) interesting information was obtained differences were found between two groups of populations when studying interpopulation variation which are populations timed to the mountain tundra belt on the one hand, and populations timed to near-snowy lawns and river meadows on the other hand. In the second group of populations, a tendency towards a clear predominance of features which characterize the general habit of the plant (height of sprouts, their number, leaf size, etc.) is noted. Therefore, these environmental conditions can be considered optimal for *Rh. rosea* (Vedernikova et al., 2000). According to our studies, it has been established that the ecological-coenotic conditions of *Rh. rosea* habitats in the studied region are timed to the alpine and subalpine belts of mountains in the altitude limit of 1700–2400 m above sea level. A

well-formed vegetation cover in the forest and subalpine belts gradually displaces *Rh. rosea* from the phytocenoses composition or makes it impossible to penetrate into their composition.

8 age periods were found in the populations which were studied by us. However, senile (s) individuals were not found in the populations of *Rh. rosea* on the Ivanovsky ridge. Age spectra of *Rh. rosea* in different places of the Ivanovsky ridge are of the same type, and their absolute maximum in all cases falls on adults which belong to the generative period. This can be explained by good adaptability to vegetative reproduction. Seed reproduction under extreme conditions is not capable to fully support the regeneration of species populations.

Some scientists assume that the duration of ontogenesis of *Rh. rosea* is 50–55 years old, which coincides with the data on *Rh. rosea* ontogenesis in the adjacent territories of Altai mountains (Adamczak et al., 2016). According to our data, it can be noted that the ontogenesis of *Rh. rosea* lasts 50–55 years, sometimes even more.

Conclusions

Rh. rosea in the study region lives on damp mossy rocks, rocky slopes, overgrown moraines and along the banks of mountain rivers in the upper limit of cedar-larch forests, subalpine and alpine belts, in the altitude limit of 1700–2400 m. The species is found in the high mountain ranges of the Kazakh Altai and Saur-Tarabagatai. Optimal conditions for the existence of the species open moon-river habitats and river valleys extreme habitat conditions should include heavily overgrown areas of sedge-grass and birch-moss communities. In *Rh. rosea* populations, it is most commonly found with *Schulzia crinita*, *Achillea ledebourii*, *Doronicum altaicum*, *Macropodium nivale*, *Hylotelephium telephium*, *Rhodiola algida*, *Carex capillaris*, *C. aterrima*, *C. stenocarpa*, *Euphorbia pilosa*, *Trifolium lupinast*. In the ontogenesis of *Rh. rosea*, all age-related conditions were identified except for senile (s) individuals, the life expectancy is 50–55 years. The analysis of the species composition of communities with the participation of *Rh. rosea* showed that the leading families in terms of the number of species are *Poaceae*, *Ranunculaceae*, *Asteraceae*, *Rosaceae* and *Caryophyllaceae*, *Apiaceae*, *Fabaceae*; the genera *Carex*, *Aconitum*, *Dracocephalum*, *Festuca*, *Pedicularis*, *Poa*, *Salix* predominate in the generic spectrum; the ecological groups are dominated by psychrophytes, mesophytes mesopsychophytes; the Asian, Eurasian, and Antarctic groups of habitats are most richly represented in the chronological aspect; life forms according to Serebryakov (1962) are represented with a predominance of rod-rooted, brush – rooted, short-rooted and long-rooted grasses; life forms according to Raunkiaer (1934) are shown with an overwhelming majority-Hemicryptophytes (74%).

Abbreviations

Projective cover (PC), Commonwealth of Independent States (CIS), World Health Organization (WHO), Plants of the World Online (POWO), Altai highland flora (AHF)

Declarations

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Availability of data and materials

The data used and analyzed in this study can be provided from the corresponding author for scientific, non-profit purpose.

Ethics approval and consent to participate

Not applicable, the study involves no human participants.

Consent for publication

Not applicable.

Conflicting interests: The authors declare no conflict of interest.

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Figures

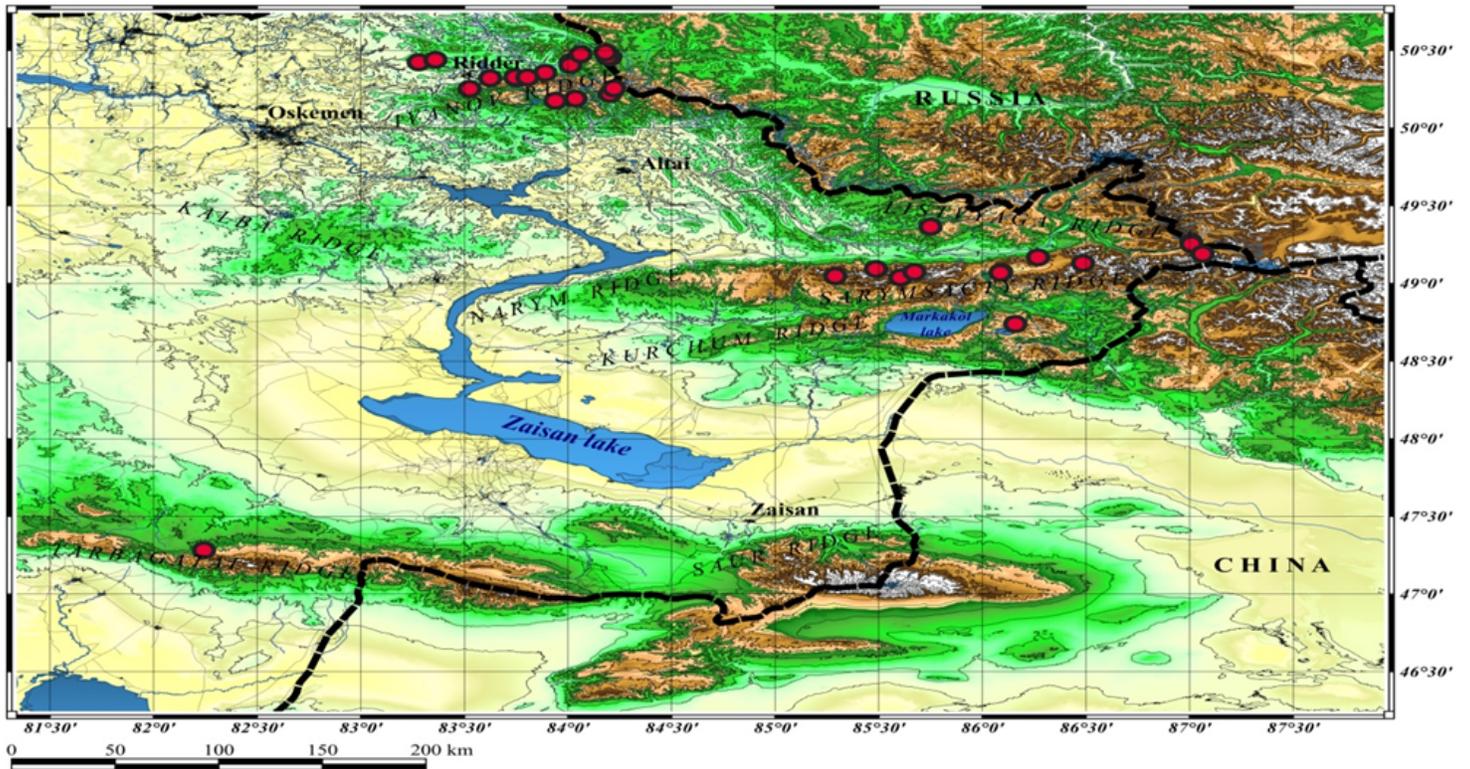


Figure 1

Distribution of *Rh. rosea* in East Kazakhstan Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

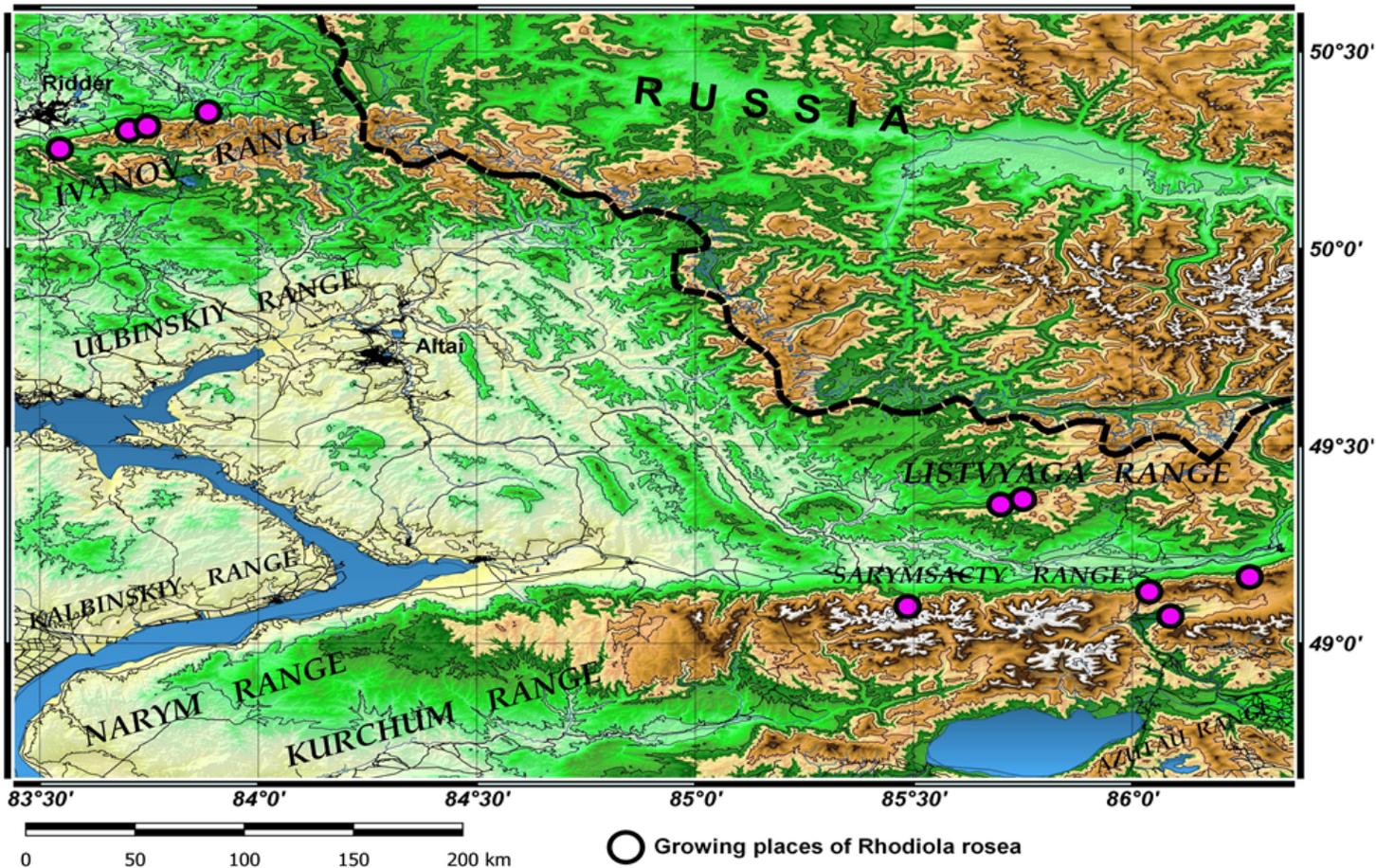


Figure 2

Scheme map of studied Population locations of *Rh. rosea* Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

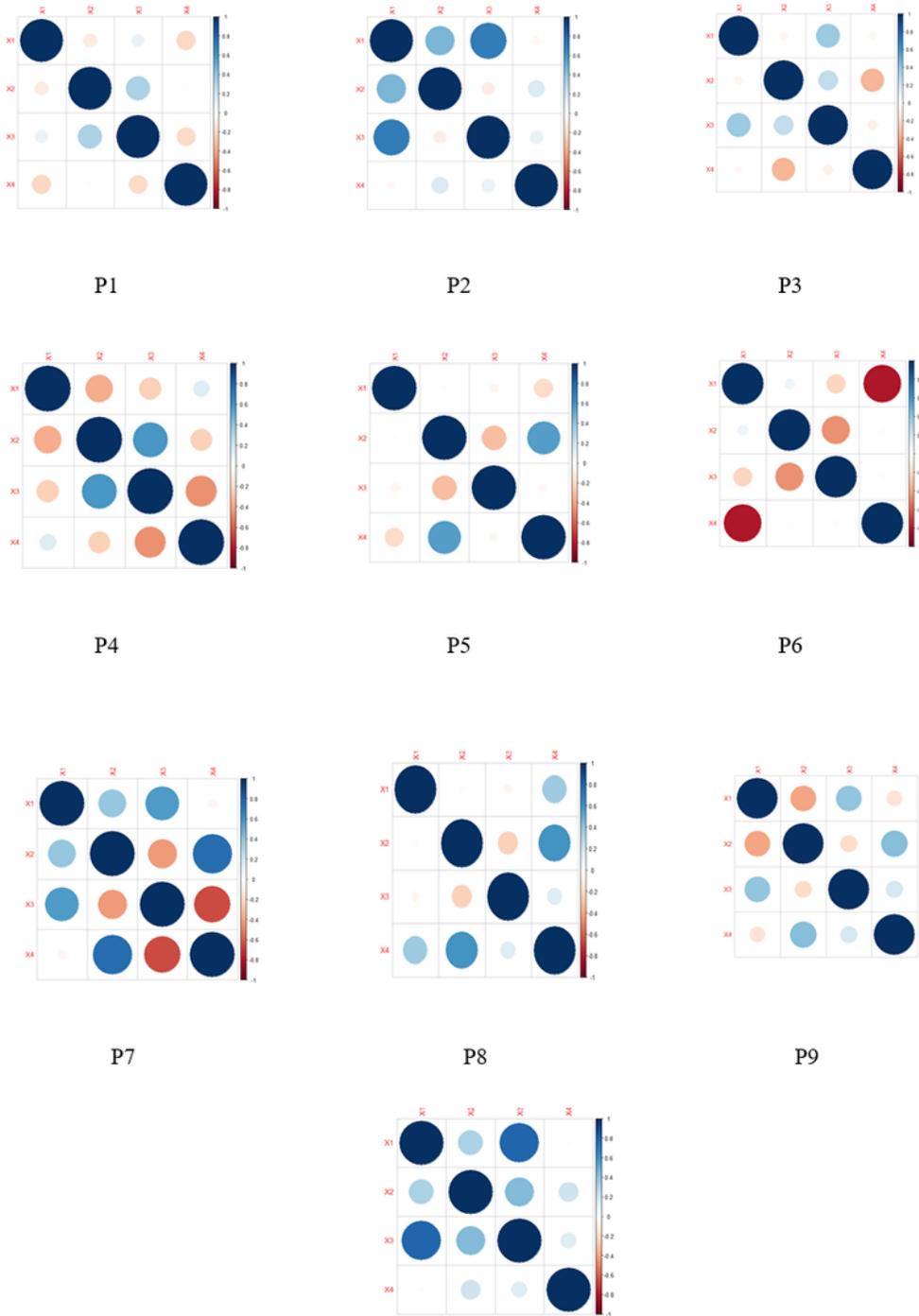


Figure 3

Correlation analysis of morphometric parameters and quantitative indicators of *Rh. rosea* within populations, Note: Correlations with $P < 0.05$ are highlighted in color. The color indicates either positive (blue) or negative (red) correlation. (X1- Number of adult specimens per 1 m²; X2- Height of generative species at the time of flowering (cm); X3- The number of sprouts per a specimens (pcs); X4- Inflorescence diameter (cm))

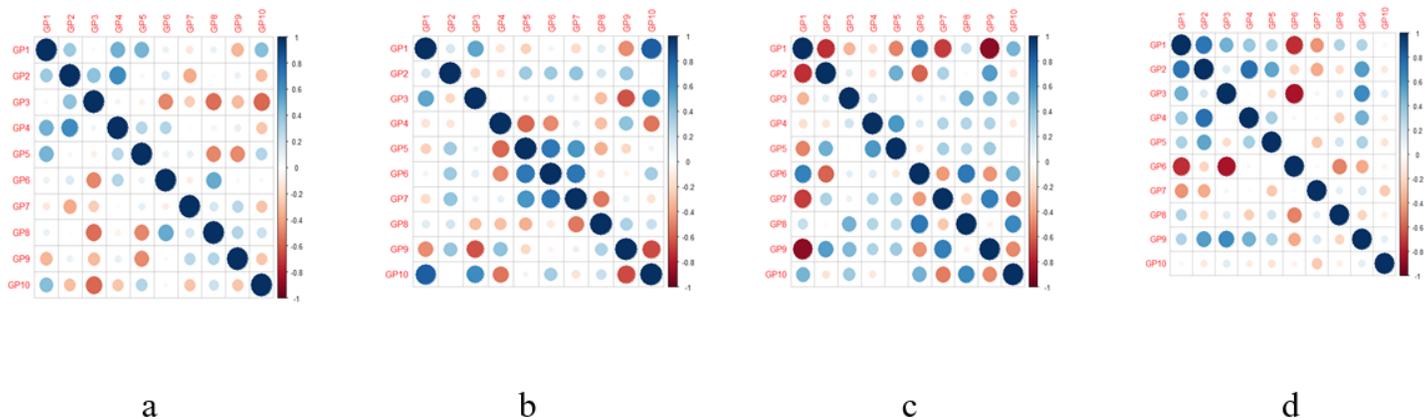


Figure 4

Correlation analysis of morphological and quantitative indicators of *Rh. rosea* between the studied populations, Note: Correlations with $P < 0.05$ are highlighted in color. The color indicates either positive (blue) or negative (red) correlation. Populations - GP1-GP10. (a - correlation of diameter of inflorescences; b - correlation of number of sprouts per one specimen; c- correlation of number of adult specimen per 1 m²; d - correlation of height generative species)

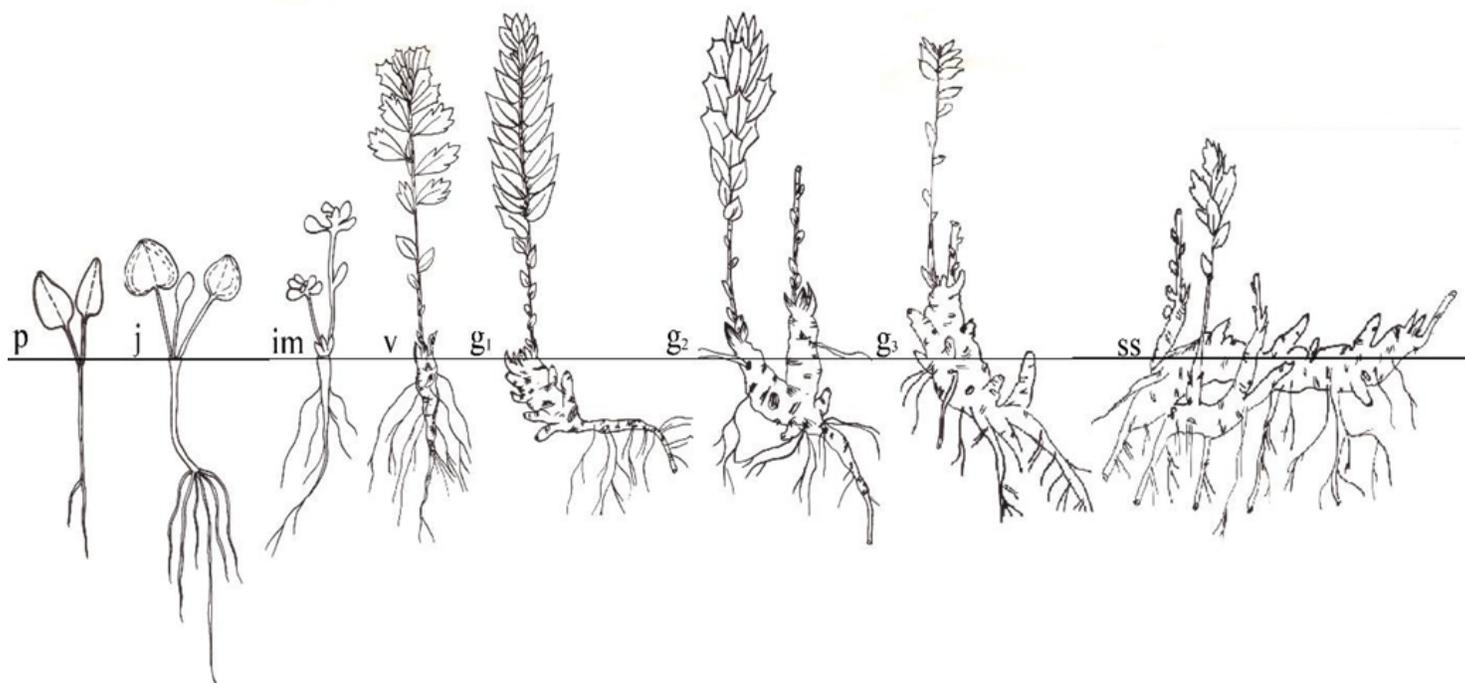


Figure 5

Ontogenesis of *Rh. rosea* : p – plantlets; j – juvenile; im – immature, v – virginile, g1 – young generative, g2 – mature generative; g3 – old generative; s – senile (old vegetative).

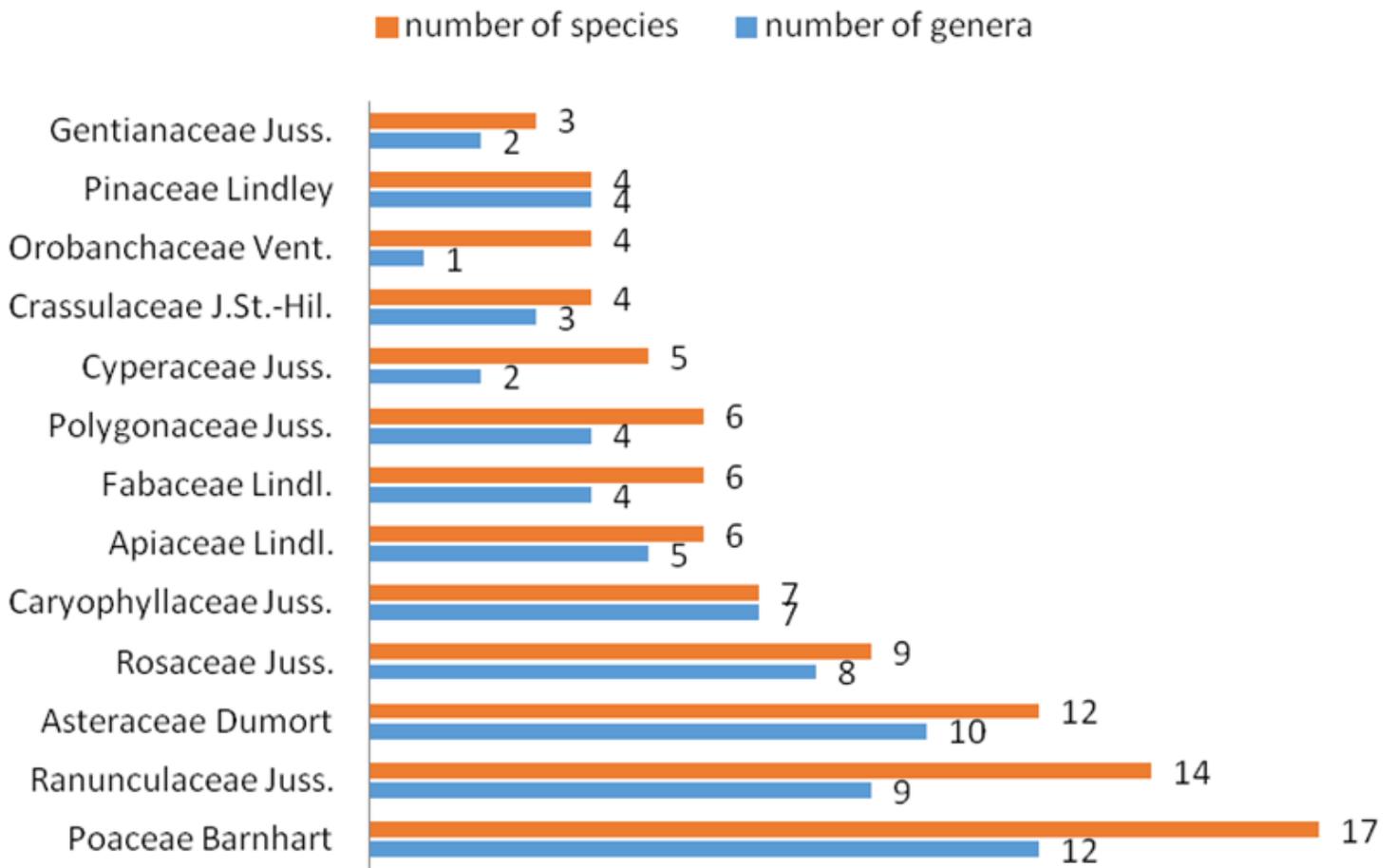


Figure 6

Analysis of leading families of Rh. rosea composition of the flora

■ I ■ II ■ III ■ IV ■ V

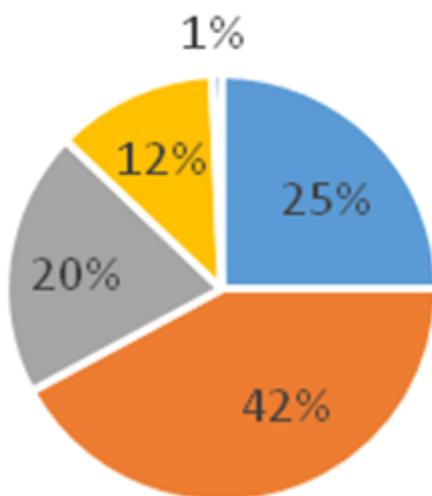


Figure 7

Analysis of the occurrence of species in the Rh. rosea composition of the flora

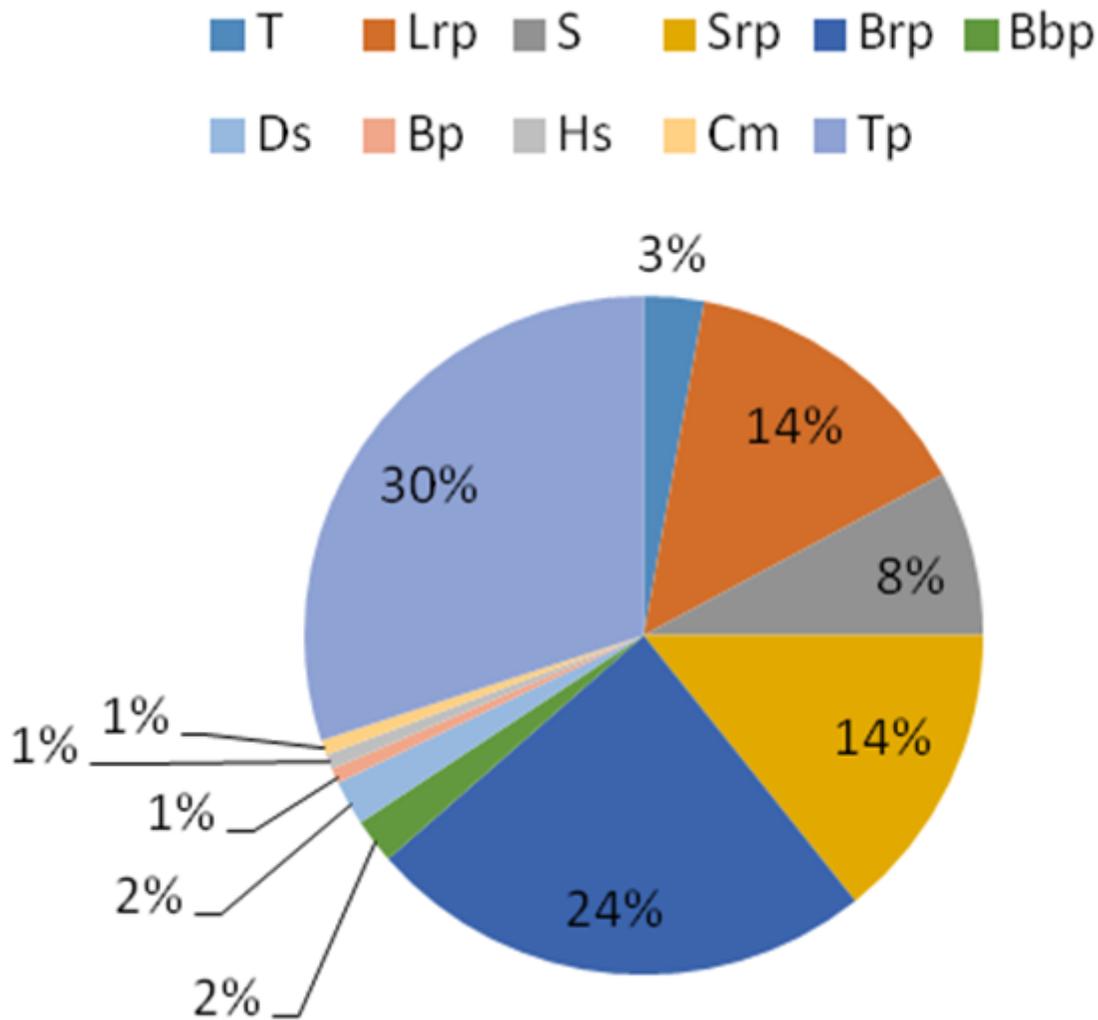


Figure 8

Life forms analysis of species composition of Rh. rosea composition of the flora: T – tree; S – shrub; Hs – half-shrub; Ds – dwarfshrub; Lrp – long rhizomatous plant; Srp – short rhizomatous plants; Bbp – bulbotuberiferous plants; Tp – taproot plants; Brp – brushy root plants; Cm – club-moss.

■ H ■ GM ■ HP ■ X ■ XPt ■ M ■ MX ■ MP ■ MPt ■ Cm ■ P

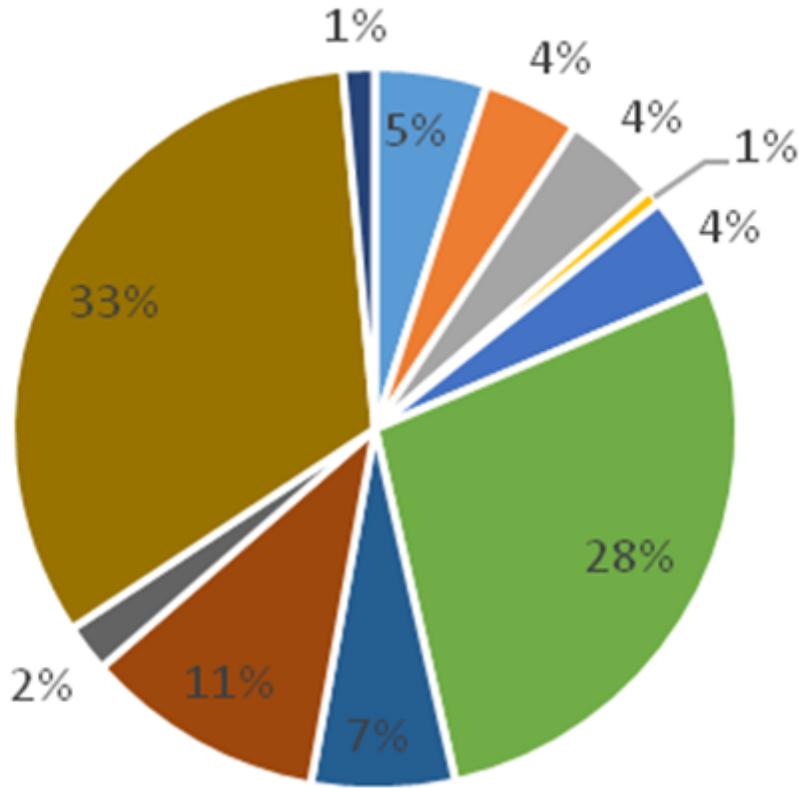


Figure 9

Analysis of ecological groups composition of the flora of *Rh. rosea* species populations: H - hygrophytes, GM—hygromesophytes, HP- hygropsychrophytes, X- xerophytes, XPt- xeropetrophyte, MX - mesoxerophytes, MP - mesopsychrophytes, X - xerophytes, XPt - xeropetrophyte, P - psychrophytes, MPt - mesopetrophytes.

■ cosm. ■ holarc. ■ euras. ■ north-as.
■ central-as. ■ tur. ■ Alt.

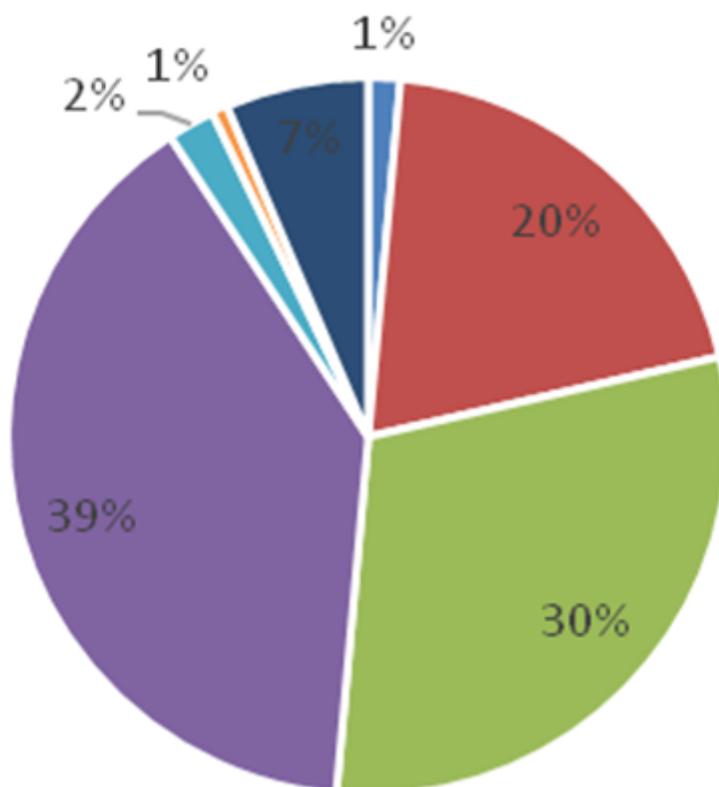


Figure 10

Chorological analysis of *Rh. rosea* composition of the flora: cosm. - cosmopolitan; holarc. - Holarctic; euras. - Eurasian; north-as. - north Asian; tur. - Turanian; Alt - Altai (endemics of the Altai-Sayan botanical-geographical province).

MF NF H HC C

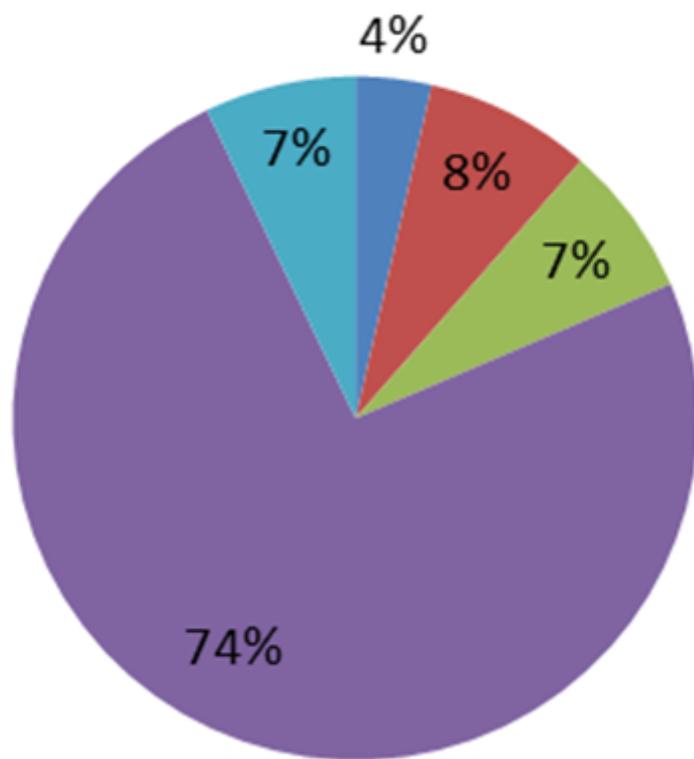


Figure 11

Analysis of life forms of *Rh. rosea* composition of the flora species (Raunkiaer, 1934)