

# ***Paeonia hybrida* Pall. as a Rare and Endangered Species of Steppe Communities in Kulunda: Biology, Ecology, Cenotic Characteristics**

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**Abstract.** *Paeonia hybrida* Pall. is a highly localized species, spread on the Priobskoye plateau, foothills and low-mountains of Altai, in the northeastern and eastern parts of Kazakhstan. The aim of the study was to study cenopopulations and features of phytocenoses with the participation of *P. hybrida* in Kulunda and on the Priobskoye plateau. The characterization of the communities is based on 13 complete geobotanical descriptions carried out on 100 m<sup>2</sup> test plots in Volchikhinsky, Mikhailovsky and Topchikhinsky districts. When identifying vegetation syntaxa, we used the interpretation of E.M. Lavrenko. Taxonomic, ecological, chorological and analysis of life forms was performed according to I.G. Serebryakov and K. Raunkier. The ontogenetic periods of *P. hybrida* were studied by the method of T.A. Rabotnov taking into account the indices of age states by A.A. Uranova. In the period of 2013–2020 the authors identified 13 *P. hybrida* cenopopulations in two classes of formations – meadow and true steppes. The share of *P. hybrida* in the herbage was 5–15%. More often the species is found in shrub communities of meadow and true steppes. In the dry-steppe zone of Kulunda, *P. hybrida* has preserved in the flat areas between dividing ridges, on gentle ridges, slopes of gullies, coarse slopes and along the deltas of ancient runoff hollows. The characteristic features of the habitats make it possible to classify the steppe peony as a mesoxerophyte. The ontogenesis of *P. hybrida* is characterized by latent, virginile, and generative periods.

## **1. Introduction**

*Paeonia hybrida* Pall. has a narrow range stretching southwestwards from the eastern part of the Priobskoye plateau and the southeastern foothills of the Salair ridge to the Pamir-Alai [1, 2]. Outside of Russia, it is found only in the northeastern and eastern Kazakhstan [3].

*Paeonia hybrida* is a mesoxerophyte, a facultative petrophyte. It is predominantly a steppe species. It grows in meadow and true steppes, in thickets of steppe shrubs, in shrubby stony steppes, screes, on the slopes of the hills in the steppe, edges of coniferous and mixed forests of low and middle mountains, along river banks and at the bottoms of ravines, where the seeds are washed down [4]. On plains and in low mountains, it occurs sporadically as small isolated loci preserved in inarable places (hills, thickets of shrubs) [5]. Modern studies of the population genetic structure of *P. hybrida* in the Kulunda steppe have not been able to identify the factors of population differentiation: spatial distance, floristic composition and climate do not significantly affect the genetic structure of the species [6].

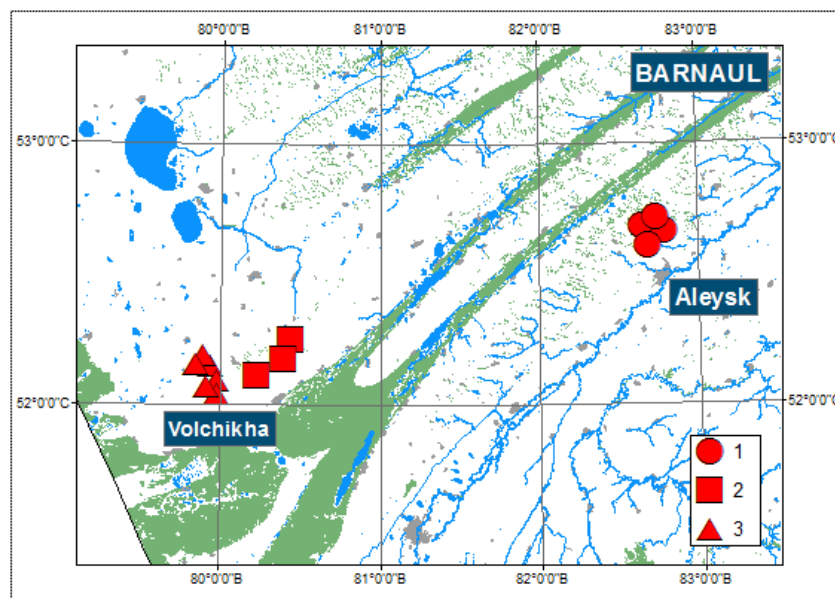
It is rare in the mountains, as a rule, these are single individuals or small populations of *P. hybrida*, which tend to grow on the south-facing slopes, where the growing conditions are more severe. In summer, the slopes are very dry due to the intense evaporation of water, and in winter, they freeze more due to the snow blow-out. I.V. Vereshchagina [7] believed that *P. hybrida* grows on the southern slopes, since the vegetation cover is never closed here and the cenotic pressure is weaker. It can withstand the competition with forbs only in mesophilic conditions. It prefers carbonate rocks and chernozems of various types [4].

In natural conditions, the steppe peony reproduces only with seeds, which germinate only after 10–16 months. According to the M.G. Nikolaeva classification [8], the steppe peony seeds have a deep morphophysiological epicotylar dormancy type B-V3e, which results from the action of a strong physiological mechanism of seed germination inhibition. Peony seeds contain such hormones as indoleacetic and abscisic acids, which inhibit germination [9].

In the territory of Altai krai, the state of *P. hybrida* local populations was studied by I.V. Vereshchagina in the 1960s-80s. In recent decades, the natural communities where *P. hybrida* was previously found have been greatly modified by the human economic activity. The species is limited by plowing of habitats, gathering for bouquets, intensive grazing, spring burns and fires [10]. *P. hybrida* has experienced the strongest anthropogenic load in the flat areas and has preserved only on inarable lands, i.e. in thickets of bushes and on the hills untouched by plows. This rare and endangered species of Altai krai requires a modern assessment of its distribution in the territory of the region. Therefore, the purpose of this work was to study the populations of the species and the features of the phytocenoses with the participation of *P. hybrida* in Kulunda and on the Priobskoye plateau.

## 2. Materials and Methods

In 2013–2020, 13 coenopopulations of the *Paeonia hybrida* were studied. The characteristics of the communities are based on 13 complete geobotanical descriptions carried out at the in the Volchikhinskiy, Mikhailovskiy and Topchikhinskiy districts (figure 1).



**Figure 1.** Distribution points in the districts:  
1 – Topchikhinskiy, 2 – Volchikhinskiy, 3 – Mikhailovskiy.

Topchikhinskiy district is located in the central part of Altai krai, on the Priobskoye plateau. The relief of the territory is flat with occasional hills. The climate of the district is moderately continental. The absolute maximum temperatures account for July (+ 37°C), the minimum accounts for January (–

38–40°C). The average temperature in January is -14°C, in July + 20°C. The annual amount of precipitation is about 450 mm. Soils are chernozem. In the northwestern part of the district, there is the Barnaul ribbon forest [11, 12].

Volchikhinskiy and Mikhailovski districts are located in the southwestern part of Altai krai. The territory of the districts is confined to the southern part of the Kulunda lowland, to the dry-steppe subzone of Kulunda (the steppe zone) [12]. The climate of the districts is markedly continental with cold dry winters and hot dry summers. The absolute maximum temperatures account for July (+38 +41°C), the minimum accounts for January (-41–51°C). The average temperature is -17.6°C in January, +21°C in July. The annual precipitation is 230–350 mm. The predominant soil types are sandy loam and chestnut chernozems. One third of the Volchikhinskiy district is covered with pine forests. Lack of moisture and excessive dryness of the air cause soil and air droughts, dry winds and dust storms.

In all three districts, the transition of the average daily air temperature through +5°C falls on the third decade of April. The frost-free period lasts for 117–126 days. The growing degree-day units range from 2450 to 2600°C.

The size of the site for geobotanical descriptions equals 100 m<sup>2</sup>. The abundance of species (the Drude scale), the projective cover (% of the total area), and the frequency of species were used as quantitative characteristics. When identifying vegetation syntaxa, we applied the E.M. Lavrenko interpretation [13].

Identification of the steppe peony ontogenetic periods was carried out according to the T.A. Rabotnov classification of age states [14]. Age indices are applied after A.A. Uranov [15]. When studying the floral composition of communities with the participation of *P. hybrida*, additional analyses were carried out: taxonomic, ecological, and chorological analysis of life forms by K. Raunkier [16] and I. G. Serebryakov [17].

### 3. Result and Discussion

**Morphological features.** *Paeonia hybrida* is a rhizomatous herbaceous polycarpic plant with tuberous thickened roots. There are morphological descriptions of *P. hybrida* throughout its range [7, 18, 19]. For the studied coenopopulations of *P. hybrida* of Kulunda and the Priobsky Plateau, it was noted that the morphological parameters of the vegetative and generative parts are different, but fit into the range of variation of the characters indicated for this species by other authors. Thus, it was noted that the size of the root tubers extending from the thick root, formed as a result of thickening of the accessory roots, ranged from 2.5 to 13 cm, and the unbranched straight stems had a height of 15 to 20 cm.

The width of the thrice pinnate leaves varied from 3-10 mm. The cup-shaped flowers had a span of 5-8 cm in diameter. Peony petals in all the observed populations were purple-pink in color, including 8-12 pieces (figure 2). The apocarp gynoecium consisted of 3-5 carpels, rarely of 2.



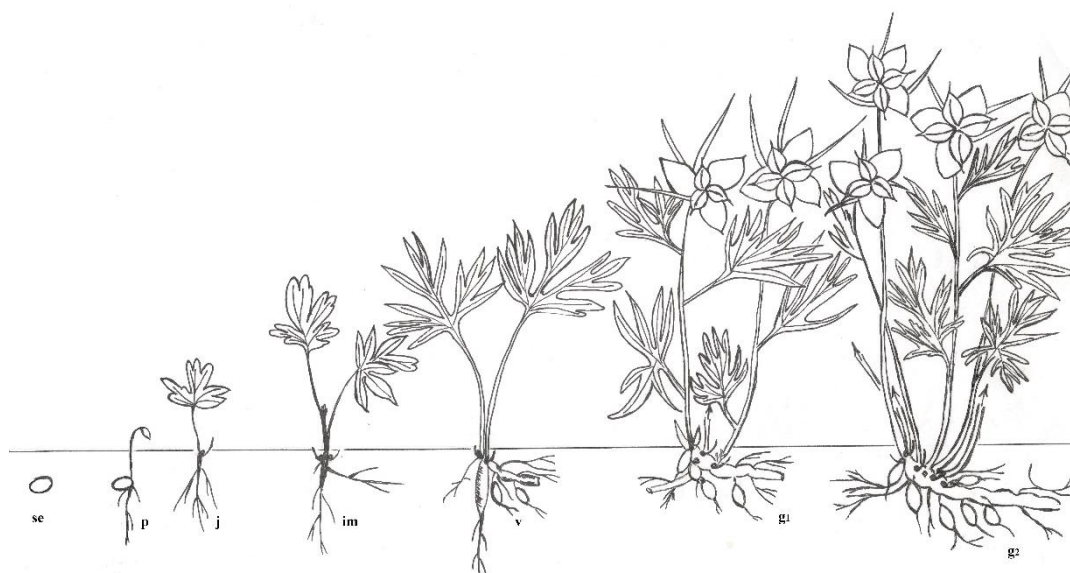
**Figure 2.** (A) – blooming, May 2020. (Mikhailovski district, vicinity of Aschegul), (B) – mature quinquefollicle (photo by T.V. Korniyevskaya)

The fruit is follicular, consisting of 3-5, rarely 2-4 follicles. Follicles are oblong-oval, sharply deflected from each other, densely pubescent with short tomentose hairs. Follicle length is 12-30 (21) mm, width - 8-20 (13) mm. The walls of the follicle are dense, leathery.

Seeds are oval-elliptical with a thick, shiny, dark-brown, almost black, coat. They are arranged in two rows on both sides of the ventral suture. They have a well-defined raphe. The seed size varies from 3 to 5 mm (in length) and from 2 to 4 mm (in width). The number of seeds in a follicle varies greatly from 1 to 11, the average number is 6-7.

### 3.1. Ontogenesis

In cenopopulations of *P. hybrida* for the first time in the history of study on the territory of Kulunda and on the Priobskoye plateau, we observed three ontogenetic periods and seven age states: latent (dormant seeds), virginile (seedlings, juvenile, immature, young vegetative), and generative (young generative and mature generative) (figure 3).



**Figure 3.** *P. hybrida* ontogenesis (picture by T.V. Korniyevskaya): se – latent period, p – seedlings, j – juvenile, im – immature, v – virginile, g1 – young generative, g2 – mature generative.

The latent period in a peony is represented by dormant seeds (se), which turn black when mature.

Virginile (pre-generative period) includes ontogenetic states from germination to the appearance of the first flower. Seedlings were detected in the populations (p). Germination is hypogeal. The cotyledons remain in the seed coat and fall off after the first true leaves appear.

The juvenile period of development (j) is characterized by a strong transformation of the leaf blade, which is dissected into several lobes, most often into three ones. The leaf petioles are elongated. At the end of the first year of vegetation, the seedlings develop trifoliate leaves and a thickened main root. Renewal buds are formed in the leaf axils. The size of young plants in the first year of life is 3–4 cm. The period lasts for 3–4 years. At the end of the period, the plant height is 15–20 cm. Young shoots develop from lateral buds. A shift from the monopodial type of branching to the sympodial one is observed. The aerial part of the shoot dies off every year prior hibernating.

The generative period of *P. hybrida* starts at 4–5 years of age. Renewal buds are located at the base of the stems. In young generative individuals (g1), a few elongated shoots are formed, while bottom leaves are not developed. The period lasts for 6–8 years. Then the individuals enter the middle-aged generative state (g2). This period is characterized by the maximum biomass growth and the maximum

seed productivity. The old generative state (g3) was found in a small number of *P. hybrida* in the Mikhailovskiy district (in the vicinity of the Poluyamki village). Such plants were characterized by the dominance of the processes of decay over the processes of growth and the weakening of reproductive functions. Similar patterns were observed in all 13 cenopopulations.

### 3.2. Characteristics of plant communities with the *P. hybrida* participation

The species can be present in both herbaceous and shrub communities. Below is the classification of the steppe cenoses with the participation of *P. hybrida*, where the peony is either one of the dominant or one of codominant species.

Formation class – meadow steppes

Group of formations – forb-grasses meadow steppes

Formation: rich forb-grasses steppes (*Stipa pennata* + *Poa angustifolia* + *Calamagrostis epigeios* + *Peucedanum morisonii* + *Filipendula vulgaris* + *Fragaria viridis*)

association forb-grasses (*Stipa pennata* + *Poa angustifolia* + *Phlomis tuberosa* + *Ferula soongarica*)

Formation: forb-fescue-feathergrass steppe (*Stipa pennata* + *Festuca pseudovina* + *Fragaria viridis* + *Filipendula vulgaris*)

association forb-fescue-feathergrass (*Stipa pennata* + *Festuca pseudovina* + *Peucedanum morisonii* + *Artemisia glauca*)

association peony- hog's-fennel-sedge (*Carex supina* + *Peucedanum morisonii* + *Paeonia hybrida*)

association peony- hog's-fennel-sedge-feathergrass (*Stipa pennata* + *Carex supina* + *Peucedanum morisonii* + *Paeonia hybrida*)

association iris-fescue-ferula (*Ferula soongarica* + *Festuca pseudovina* + *Iris halophila*)

Formation class – true steppes

Group of formations – thick bunchgrass true steppes

Formation: forb-fescue-feathergrass (*Stipa capillata* + *Festuca valesiaca* + *Artemisia frigida* + *A. austriaca* + *Thymus marschallianus*)

association herbs-fescue-feathergrass (*Stipa capillata* + *Festuca valesiaca* + *Achillea millefolium* + *Thalictrum minus*)

association peony-bluegrass-feathergrass (*Stipa capillata* + *Poa angustifolia* + *Paeonia hybrida*)

When characterizing the communities with *Paeonia hybrida*, communities with shrubs are viewed separately: strawberry-caragana-feathergrass (*Stipa pennata* + *Caragana frutex* + *Fragaria viridis*), iris-caragana-feathergrass (*Stipa capillata* + *Caragana frutex* + *Iris halophila*), forb-feathergrass-caragana steppe associations (*Stipa pennata* + *Caragana frutex* + *Fragaria viridis*), iris-caragana-spatula-weed (*Stipa capillata* + *Caragana frutex* + *Iris haganlophila*), forbgrasses-feathergrass-caragana (*Caragana frutex* + *Stipa pennata* + *Filipendula vulgaris* + *Fragaria viridis*).

These communities are typical of the plains in the deltas of the ancient runoff hollows on chestnut and dark chestnut soils in the vicinity of the Parfenovo village, Topchikhinskiy district.

The shrub sublayer is represented by *Caragana frutex* (L.) K. Koch with a projective cover of up to 30%, and a height of up to 1.2 m. It is the basis of the dominant species. Among the shrubs, single specimens of *Spiraea crenata* L., *Rosa laxa* Retz. are found, however, their projective cover rarely exceeds 5%. The main dominants of the herbaceous layer are sod narrow-leaved grasses *Stipa pennata* L. and *S. capillata* L.

*Fragaria viridis* (Duchesne) Weston and *Filipendula vulgaris* Moench, which reflect the specificity of the ecotope of the areas bordering on the forest, should be classified as characteristic species with high constancy but not abundance values.

Highly abundant species are the following (cop-sp): *Artemisia austriaca* Jacq., *A. frigida* Willd., *Caragana frutex*, *Festuca pseudovina* Hack. ex Wiesb., *F. valesiaca* Gaudin, *Fragaria viridis* (Duchesne) Weston, *Galium verum* L., *Koeleria glauca* (Spreng.) DC., *Paeonia hybrida*, *Phleum phleoides* (L.) H. Karst., *Phlomis tuberosa* (L.) Moench, *Potentilla bifurca* L., *P. canescens*

Besser, *Rosa laxa*, *Salvia stepposa* Des.-Shost., *Spiraea crenata*, *Stipa capillata*, *S. pennata*, *Thymus marschallianus* Willd.

The herbage normally consists of three sublayers. The first sublayer, 90–110 cm high, is composed of generative shoots of large grasses (*Stipa capillata*, *S. pennata*) and shrubs. The most of the second sublayer (50–60 cm) is made up of meadow-steppe grasses and forbs: *Phleum phleoides*, *Poa angustifolia*, *Koeleria cristata*, *Galium verum*, *Phlomis tuberosa*, *Medicago falcata*, *Achillea asiatica*, *Filipendula vulgaris*, *Onosma simplicissima*. The third sublayer (up to 15 cm) is represented by *Carex supina*, *C. pediformis*, *Fragaria viridis*.

The herbage of the characterized communities is thick and homogenous, its projective cover reaches 90–100%.

In general, the abundance of species varies from 22 to 31 species per 100 m<sup>2</sup>. The *Paeonia hybrida* share reaches 8% of the total projective cover.

Formation class – meadow steppes

Group of formations – forb-grasses meadow steppes

Formation: rich forb-grasses steppes (*Stipa pennata* + *Poa angustifolia* + *Calamagrostis epigeios* + *Peucedanum morisonii* + *Filipendula vulgaris* + *Fragaria viridis*)

association forb-grasses meadow (*Stipa pennata* + *Poa angustifolia* + *Phlomis tuberosa* + *Ferula soongarica*)

The identified community grows in the Volchikhinskiy district on gentle slopes with birch outliers (leached and common chernozems) and gully forests (gray forest soils). Grasses form the basis of the herbage: *Stipa pennata*, *S. capillata*, *Poa angustifolia*. The dominants encompass a group of mostly meadow-steppe mesoxerophytes and xeromesophytes: *Phlomis tuberosa*, *Galium verum*, *Salvia stepposa*, *Iris ruthenica* Ker Gawl. Single specimens are represented by shrubs (*Cotoneaster melanocarpus* Fisch. ex Blytt, *Spiraea crenata*), which projective cover doesn't exceed 3%. Herbs include the following species: *Medicago falcata*, *Campanula sibirica* L., *Achillea asiatica*, *Filipendula vulgaris*, *Salvia stepposa*, *Peucedanum morisonii* Besser ex Spreng.

Highly abundant species are the following (cop-sp): *Bromopsis inermis*, *Filipendula vulgaris*, *Medicago falcata*, *Paeonia hybrida*, *Poa angustifolia*, *Salvia stepposa*, *Stipa capillata*, *S. pennata*.

The herbage consists of two sublayers. The first sublayer, 80 cm high, is represented by *Ferula soongarica* Pall. ex Spreng, generative shoots of *Stipa pennata*, *S. capillata*, *Poa angustifolia*, *Bromopsis inermis*. The second sublayer (up to 30 cm) is made up of vegetative shoots of grasses and forbs (*Filipendula vulgaris*, *Salvia stepposa*, *Medicago falcata*, *Euphorbia virgata* Waldst. & Kit.).

The total herbage projective cover is 70%. The abundance of species is 27 species per 100 m<sup>2</sup>. The *Paeonia hybrida* share reaches 5% of the total projective cover.

Formation: forb-fescue-feathergrass steppes (*Stipa pennata* + *Festuca pseudovina* + *Fragaria viridis* + *Filipendula vulgaris*)

association herb-fescue-feathergrass (*Stipa pennata* + *Festuca pseudovina* + *Peucedanum morisonii* + *Artemisia glauca*)

association peony-hog's fennel-sedge (*Carex supina* + *Peucedanum morisonii* + *Paeonia hybrida*)

association peony-hog's fennel-sedge feathergrass (*Stipa pennata* + *Carex supina* + *Peucedanum morisonii* + *Paeonia hybrida*)

association iris-fescue-ferula (*Ferula soongarica* + *Festuca pseudovina* + *Iris halophila*)

The identified communities grow in the Volchikhinskiy (in the vicinity of the Kominintern village, the buried channel of the Kabanikha River) and Mikhailovskiy District (the buried channel of the Aschegul River) on solonetz chernozems along the flat areas between ridges and gentle ridges, on the slopes of gullies.

These steppe communities are identified by the main edifier, dominant, zonal species of meadow steppes – *Stipa pennata* L. These are no longer rich forb steppes, and their projective cover ranges from 50 to 60%. The edifier is *Stipa pennata*, while co-edifiers are: *Festuca pseudovina*, *Peucedanum morisonii*, *Paeonia hybrida*, *Iris halophila*. Shrubs are represented by single species: *Caragana arborescens* Lam., *Cotoneaster melanocarpus*, *Rosa laxa*, which projective cover doesn't exceed 3%.



Highly abundant species are the following (cop-sp): *Artemisia glauca*, *Caragana frutex*, *Carex duriuscula*, *Festuca pseudovina*, *F. valesiaca*, *Galium ruthenicum* Willd., *Iris halophila*, *Medicago falcata*, *Paeonia hybrida*, *Peucedanum morisonii*, *Phlomis tuberosa*, *Potentilla humifusa*, *Salvia stepposa*, *Stipa capillata*, *S. pennata*.

The herbage is mostly three-sub layered. The first sublayer, 60–70 cm high, is composed of generative shoots of *Stipa pennata*, *Peucedanum morisonii*. The most of the second sublayer (30–40 cm) is represented by *Euphorbia virgata*, *Adonis villosa* Ledeb., *Potentilla humifusa*, *Galium ruthenicum*, *Iris halophila*, *Paeonia hybrida*, vegetative shoots of *Stipa pennata*, *Peucedanum morisonii*. The third sublayer, 15 cm high, is represented by the following species: *Artemisia latifolia* Ledeb., *A. frigida* Willd., *Potentilla humifusa*.

The species abundance is 25 species per 100 m<sup>2</sup>. The *Paeonia hybrida* share reaches 15% of the total projective cover.

Formation class – true steppes

Group of formations – thick bunchgrass true steppes

Formation: forb-fescue-feathergrass (*Stipa capillata* + *Festuca valesiaca* + *Artemisia frigida* + *A. austriaca* + *Thymus marschallianus*)

association herbs-fescue-feathergrass (*Stipa capillata* + *Festuca valesiaca* + *Achillea millefolium* + *Thalictrum minus*)

association peony-bluegrass-feathergrass (*Stipa capillata* + *Poa angustifolia* + *Paeonia hybrida*)

Communities of the associations grow in Mikhailovskiy (in the vicinity of the Poluyamki village) and Topkhichinskiy districts (in the vicinity of the Parfyonovo village) on gentle slopes on southern chernozems.

The role of the edifier belongs to the firm bunch grass – feather grass (*Stipa capillata*). Highly abundant species are the following (cop-sp): *Artemisia glauca*, *Bromopsis inermis*, *Carex duriuscula*, *Ferula soongarica*, *Festuca pseudovina*, *Koeleria glauca*, *Potentilla bifurca*, *P. humifusa*, *Paeonia hybrida*, *Poa angustifolia*, *Stipa capillata*, *S. pennata*, *Thymus marschallianus*.

The herbage normally consists of three sublayers. The first sublayer, 60–70 cm high, is represented by generative shoots of sod steppe grasses *Stipa capillata*, *Festuca valesiaca*, and *Artemisia austriaca*. The second sublayer (30 cm) is made up of vegetative shoots of *Stipa capillata*, *Koeleria glauca*, *Festuca valesiaca*, *Helictotrichon desertorum* (Less.) Nevski; group of meadow-forest mesophytic forb species: *Trifolium medium* L., *Origanum vulgare* L., *Achillea millefolium*, *Thalictrum minus* L., *Vicia cracca* L.; and rhizomatous grasses *Poa angustifolia* и *Calamagrostis epigeios* (L.) Roth. The third sublayer (10–15 cm) is represented by *Carex duriuscula*, *Androsace maxima* L., *Thymus marschallianus*.

The species abundance is 23 species per 100 m<sup>2</sup>. The *Paeonia hybrida* share reaches 10% of the total projective cover.

### 3.3. Floristic analysis

The studied communities feature 282 species of vascular plants belonging to 158 genera and 40 families. The leading families are *Asteraceae*, *Poaceae* and *Fabaceae*. These families are leading in the flora of Altai krai. The communities are dominated by the species with the Eurasian range type – 63.5%. The largest number of species belong to the groups of true mesophytes (37.2%), mesoxerophytes (33.7%) and true xerophytes (23%). The analysis of life forms (the K. Raunkier system) showed that hemicryptophytes – 212 species – take up the dominant position in all the studied phytocenoses. They account for 75% of the total species number, which is typical for the communities of the steppe zone. The distribution of plant species in the classification of life forms by I.G. Serebryakov showed the predominance of short-rhizome (19.5%), tap-root (17.4%) and long-rhizome (15.2%) polycarpic terrestrial grasses.

#### 4. Conclusion

When studying the distribution of the hybrid peony in the flat part of the region (Kulunda and of the Priobskoye plateau) in 2013–2020, 13 cenopopulations of the species were identified. As in most of the range, the species manifests itself as a mesoxerophyte, preferring bushy meadow and true steppes, as well as thickets of bushes. In 3 associations, the studied species is dominant (peony- hog's-fennel-sedge (*Carex supina* + *Peucedanum morisonii* + *Paeonia hybrida*), peony- hog's-fennel-sedge-feathergrass (*Stipa pennata* + *Carex supina* + *Peucedanum morisonii* + *Paeonia hybrida*), peony-bluegrass-feathergrass (*Stipa capillata* + *Poa angustifolia* + *Paeonia hybrida*)), in 5 associations (forb-feathergrass-caragana steppe associations (*Stipa pennata* + *Caragana frutex* + *Fragaria viridis*), iris-caragana-spatula-weed (*Stipa capillata* + *Caragana frutex* + *Iris hagenlophi*), forbgrasses-feathergrass-caragana (*Caragana frutex* + *Stipa pennata* + *Filipendula vulgaris* + *Fragaria viridis*), iris-fescue-ferula (*Ferula soongarica* + *Festuca pseudovina* + *Iris halophila*), forb-fescue-feathergrass (*Stipa pennata* + *Festuca pseudovina* + *Peucedanum morisonii* + *Artemisia glauca*)) – co-dominant. Its share in the herbage is 5–15%. All studied populations are characterized by 3 ontogenetic periods: latent, virginal, and generative.

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