

Rare and endangered plant species of the Chinese Altai Mountains

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Abstract: Altai (also named Altay in China) Mountain Country (Mountain System) is a unique natural region, located on the border between different floristic regimes of the Boreal and ancient Mediterranean sub-kingdoms, where distribution of plant species is actually limited. It is known to have sufficient endemic floral biodiversity in the Northern Asia. Many plants of Altai Mountain System need effective care and proper conservation measures for their survival and longer-term protection. Important Plant Area identified as the IUCN (the International Union for Conservation of Nature), specified criteria attract global attention for protection of floral biodiversity across the world. The records of 71 plant species from the Chinese Altai Mountains attributed to the criterion A and the dark conifer forests of Chinese Altai Mountains satisfied the criterion C, which may help qualify to fulfill the national obligation of the Convention on Biological Diversity.

Keywords: conservation; Important Plant Area; endemics; Altai Mountain System

1 Introduction

The global biodiversity is known to be endangered now, and suffers seriously from the destruction of natural ecosystems, often caused by unwise human activities. According to the Convention on Biological Diversity, the system of special protected areas, also known as Important Plant Area (IPA), should become the base for supporting natural plant biodiversity and for sustainable use of plant resources. IPA is identified on the basis of three main criteria, including, A—globally and regionally threatened species, B—endemic, botanical richness and C—threatened habitats (Anderson, 2003). An area satisfying at least one or more of the above mentioned criteria can be qualified to be an IPA. The IPA program offers a means of identifying the threatened plants in those areas and determining that which of them have already being protected under the existing protected area systems i.e., national parks, reserves, and sanctuaries etc.

Altai Mountains are known to be the highest (4,506 m a.s.l.) among mountain systems of Northern Asia. It is situated in the Western of Altai-Sayan eco-region (Kamelin, 2005). It stretches from 44°30'N to ap-

proximately 54°N, and lies within the territories of Russia, China, Kazakhstan and Mongolia. The division of Altai Mountains had been argued and revised for several decades (Kamelin 1973, 2005; Takhtajan, 1978; Revushkin, 1988; Wu *et al.*, 1996; Kamelin, 2005). Altai Mountains have extraordinary diversity and high endemism of floral species. Detailed manuals and guidelines for identifying IPA in Altai-Sayan eco-region has been published (Artemov *et al.*, 2007). Having taken into account all peculiarities of the Siberian Flora, the researchers made the lists A (ii), A (iii), A (iv), and considering the vast territory of Russia and its federative arrangement, Artemov *et al.* (2007) proposed the introduction of new category A (v), which includes the species of local Red Data Book. Unfortunately, this manual only covered the eco-region of Russian, whereas the Altai Mountain System of Chinese part has not been included. Thus, in the paper, we have first reviewed the history of the division, the biodiversity situation, and the status of rare and endangered species of the Altai Mountains.

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Secondly, we have tried to reveal the species of Chinese Altai flora stratified to criteria A, and have proposed the preliminary list of habitats, corresponding to criterion B and C of the IPA.

2 Materials and methods

The endemic and near endemic species were revealed, and their distribution was specified on the base of literature sources: Red Data Book of Kazakh SSR (1981), Red Data Book of Altai Republic (1996), Commission Redactorum Florae Xinjiangensis (1996), Red Data Book of Tyva Republic (1999), Red Data Book of Khakasia Republic (2002), Flora of China (Wu, 1994–2005), Red Data Book of Altaiskiy krai (2006), Red Data Book of Russian Federation (2008), Biodiversity of Altai-Sayan ecoregion and Database of plants and fungi (Biodiversity of Altai-Sayan Ecoregion, 2010).

The herbaria materials of AT, HAL, LE, MHA, MW, NS, NSK, PE, SSBG, TK and the collections of authors from Chinese parts of Altai Mountains were used to find out and specify species' distribution.

Geographic information system (GIS) software (ArcGIS 9) was used to map and digitize various floristic subdivisions of Altai Mountains to obtain the information on floristic provinces' boundaries in Chinese Altai Mountains (Kamelin, 2005).

3 Results and discussion

3.1 The history of division, the biodiversity, the rare and endangered floral species of the Altai Mountains

3.1.1 Division of Altai Mountains

Altai Mountains are located along the borders between different floristic provinces of Boreal and Ancient Mediterranean floristic sub-kingdoms (Takhtajan, 1978). It should be noticed that different authors mark these borders in different places, but all of them (Kamelin 1973, 2005; Revushkin, 1988; Wu *et al.*, 1996) accept the frontier position of Altai. According to the last division (Kamelin, 2005), Altai Mountain Country includes the ridges Saur and Tarbagatai and its flora that is supposed to be formed on the bases of at least three different floral regimes, Boreal Euro-Siberian, Steppe and Ancient Mediterranean. As suggested by Kamelin (1973, 2005), botanical-geographical subdivision of Altai is based on three fundamental regions, including Boreal Mountainous South Siberian (Altai-West-Sayan floristic province), Sub-boreal Steppe Mountainous South Altai-Dzungarian (Altai-Dzungarian, also named Altay-Junggar in China) and Steppe-Desert Central Asian (Tuvanian-Mongolian), which completely reflect the floristic peculiarities of different regions of the Altai Mountain Country (Fig. 1). According to Kamelin



Fig. 1 Scheme of botanical-geographical subdivision of Altai (Kamelin, 2005)

A: Altai province (A1: Northern Altai, A2: North-Eastern Altai, A3: Central Altai, A4: Tchulyshman, A5: Abakan-Dzhebash, A6: Khemchik). KAD: Altai-Dzungarian province (KAD1: North-Western Altai, KAD2: Kalbinsky, KAD3: Tarbagatai, KAD4: Saur, KAD5: Zaissan, KAD6: Bukhtarma, KAD7: Markakol-Kanas, KAD8: Kara-Irtysh, KAD9: Altai-Dzungarian). ZM, UM: Tuvanian-Mongolian province (ZM1: Chuya-Khobdo, ZM2: Tsagan-Gol, ZM3: Khobdo-Tonkhil; UM: South-Mongolian)

(1973, 2005), the flora of Altai Mountains belongs entirely to the Circumpolar of the Boreal sub-kingdom, but to its different sub-regions, Altai-West Sayan belonging to Euro-Siberian sub-region, whereas both Altai-Dzungarian and Tuvian-Mongolian provinces to Steppe sub-region. According to this division, Chinese Altai belongs to Altai-Dzungarian province. In China, it is represented by 6 sub-regions viz., Tarbagatai (KAD 3), Saur (KAD 4), Zaissan (KAD 5), Markakol-Kanas (KAD 7), Kara-Irtysh (KAD 8), and Altai-Dzungarian (KAD 9) (Fig. 1). Altai-Dzungarian floristic province as a whole is known to be very rich and original in floral biodiversity (Kamelin, 2005).

3.1.2 The Russian part of Altai Mountain System and the biodiversity

The Russian part of Altai Mountain System has 1,980 plants species, which perhaps is inferior to Ussury (South of Russian Far East) floristic region amongst the Asian parts of Russia (Malyshev *et al.*, 2000). Kamelin (2005) indicated the flora of vascular plants of Altai Mountains as a whole having about 2,700 species at present. And, since 1998 the number of new species from this area has been reported (Chusovliyanov, 1998; Ovchinnikova *et al.*, 2004; German *et al.*, 2006). Artemov *et al.* (2007) pointed out 252 endemic species of Altai-West Sayan floristic province as a whole (which includes other South Siberian mountains to the East Altai as well, but does not include KAD 3, KAD 4, and KAD 5 and KAD 9 (Kamelin, 2005)). Approximately, 125 species have been listed from the Altai Mountains alone. Piak *et al.* (2008) reported 288 endemic and sub-endemic (near endemic) plants of the Altai Mountain Country, which is not coincide with Artemov *et al.* (2007). The records of endemic and sub-endemic species from Altai Mountains have been extended, as new species are expected to be recorded from this poorly explored territory. Piak *et al.* (2008) has noted that over 30 endemic species have been found in this region during the last 15 years.

3.1.3 The Chinese part of Altai Mountain System and the biodiversity

Qian *et al.* (1956) subdivided the vegetation in China into 15 geo-botanical regions, recognized as 12 zones (vertical belts). In accordance with this subdivision, 3 zones of vegetation are characteristic for Chinese Altai: (1) Subarctic conifer forests (Aciculililve); it occupies

very restricted area, from the North in Altai to the West in Greater Khingan Mountains. Both of them represent the part of Siberian taiga, which wedged itself in Chinese territory. The main forest trees are conifers. Some of them are deciduous, and adapted to the cold, dry and long winter. In the forests of Altai Mountain System, *Picea excelsa* occurs on the river banks only, whereas *Larix sibirica* grows on quite elevated areas. The Southern parts and foothills of these forests are replaced gradually by forest-steppe communities and then by steppe. The meadows there are very close to West-European and Siberian ones. (2) Steppe and meadows (Terriherbosa) lies aside of sub-arctic conifer forests, mixed conifer and deciduous forests of temperate zone. From North-East to South-West in Northern Dzungarian the coverage of forests turns to be sparser with disappearance of high trees, and clear area, covered by expanded herbaceous xerophytes. Depending on the moisture conditions of this zone, it is divided into 2 sub-zones, meadow and steppe. In Altai Mountain System, meadows occupy the northern, more humid part (500 mm annual precipitation). There are mesophytic grasses and forbs, such as *Poa sibirica*, *Dactylis glomerata*, *Trisetum sibiricus*, *Anemone altaica*, *Pulsatilla flavescens*, *Paeonia anomala*, *Pedicularis* spp., *Aconitum* spp. and *Delphinium* spp. Sub-zone of dry steppe occurs at the southern part of Chinese Altai (300 mm annual precipitation). Xerophytic grasses, such as *Achnatherun splendens*, *Stipa* sp., *Cleistogenes squarrosa*, and *Koeleria* sp. are developed there. The forbs are represented by *Artemisia*, *Astragalus*, *Oxytropis*, *Potentilla*, *Serratula* and *Echinops*.

Hou (1982) indicated 3 vegetation types within Chinese Altai: (1) Needle-leaved deciduous forests (light taiga) on the mountains of the cold temperate zone or temperate zone. According to the research of Chang (1955), larch forests, being light demanding, can endure a greater degree of dryness than spruce and fir. They can be found either on dry, sunny slopes or in moist valleys and lowlands. In Chinese Altai, the dominant tree species are replaced by *Larix sibirica*, which often grows with *Pinus sibirica*. *Rhododendron dahuricum* appears frequently in the shrub layer of this forest. (2) Needle-leaved evergreen forests (dark taiga) can be seen on the mountains of temperate zone. Chen *et al.* (1964) indicated the shady coniferous forests

dominated by *Picea obovata*, *Abies sibirica* and *Pinus sibirica*, are confined to the northwestern most corner of Altai Mountains, probably due to relatively higher humid climate of the region. (3) The mountain dwarf-shrub tundra is poorly developed on the summit of the temperate high mountains of Altai. The soil is acidic in nature, and the climate is characterized by high humidity, strong winds, permafrost, and short growth season. Vegetation consists of dense growth of evergreen dwarf shrubs, mainly belonging to the Ericaceae, with about 10–20 cm height and small and tough leaves (*Vaccinium vitis-idea*, *Empetrum nigrum*) and deciduous shrubs, such as *Salix rotundifolia*, *Betula rotundifolia*.

The Vegetation Map of China (Hou *et al.*, 1982) has covered dry savannah and short grasslands, the boreal deciduous forests, boreal conifer forests, temperate (boreal) mixed forests and temperate conifer forests for the Chinese Altai Mountains.

Kamelin (2005) paid attention to great diversity of vegetation in Altai-Dzungarian floristic province, but, while describing it, he meant the province as whole, because Chinese Altai covers about 50% of the whole floristic province. Nevertheless, it should be noticed, that he founds Altai-Dzungarian floristic province to be the richest in plant species within Altai Mountains System. It contains a lot of nemoral “chernevaya” taiga species. For example, the species of *Anemone umbrosa*, *Eutrema integrifolium*, *Campanula latifolia* and *Codonopsis clematidea* are endemic to this region, whereas numerous other species are quite common within Altai Mountains System. Some species, belonging to relic “quercetal” species, have been recorded there, mainly being connected with mesophyllous bush communities. These species, such as *Daphne altaica*, *Clematis integrifolia*, *Gymnospermum altaicum*, *Potentilla rupestris* and some other floral species of the province with oak forest-steppe regions of East and Central Europe are much rare. A lot of species with different relationships and origins, such as *Sibirea laevigata*, *Dictamnus angustifolius*, *Stelleropsis altaica* etc. represent the element of Middle Asia Mountains. Flora of Zaissan and Barun-Kurai depressions contains numerous Turanian, Turanian-Dzungarian, Northern Turanian-Dzungarian desert elements (*Stipagrostis pennata*, *Carex phytoides*, *Ammodendron bifolium*, etc.) and Gobian de-

sert-steppe and desert species (*Allium polyrhizum*, *Zygophyllum xanthoxylon*, etc). In addition, Kamelin (2005) considered the flora of the province to be highly original, and adduces more than 100 endemic, such as *Limnas vereszcaginii*, *Allium caespitosum*, *A. robustum*, *Iris ludwigii* etc. So, it should be paid attention to Altai-Dzungarian floristic province as a whole, including its Kazakhstanian part, nevertheless it gives a good notion about its diversity, floral resources and reasons for their conservation.

3.2 Rare and endangered plants in Chinese Altai

All the documents mentioned above indicated the Chinese Altai territory being of high botanical value. Nevertheless, this territory, being very attractive for tourism and business, now is known to be under great anthropogenic press and its flora and vegetation need special protection. Criteria, which were recommended for IPA identification, are applicable to Chinese Altai territory. Particularly, an identification of the IPA could be a step towards realizing this program.

3.2.1 The species of Criterion A

An analysis of literature sources and herbarium materials listed above has revealed 265 endemic species. Only 32 endemic species are recorded in China (Table 1). Comparison with other countries, 171 endemic species in Russian Altai Mountains, 105 in Kazakhstan Altai Mountains and 99 in Mongolian Altai Mountains, the endemic species recorded in China are not completed.

The list of threatened species of Chinese Altai consists of 35 species (Table 2), and only one of them, *Delphinium eglandulosum* C.Y. Yang et B. Wang, is endemic to Chinese Altai and may be attributed to list A (iii). Some species under protection, i.e. *Alisma nanum* D.F.Cui, *Atraphaxis jiryschensis* C.Y. Yang et Y.L. Han, *Betula halophila* Chung ex P.C.Li, *Delphinium eglandulosum* C.Y. Yang et B.Wang, and *Erigeron songaricus* Y.Wei et Z.X are amongst the Chinese national endemics. Their distribution is limited to China only and the communities with their participation are supposed to be identified as IPA, following the recommendation A (iii) of the Convention on Biological Diversity (Anderson, 2002). In accordance with recommendations for identifying IPA, the sub-endemics (near to endemic species) are also to be protected.

Table 1 Endemic species of Chinese Altai Mountains and the distribution in the different countries

Species	China	Russia	Kazakhstan	Mongolia
<i>Delphinium eglanulosum</i> C.Y. Yang et B. Wang	+	-	-	-
<i>Delphinium inconspicuum</i> Serg.	+	+	+	+
<i>Mesostemma martjanovii</i> (Kryl.) Ikonn	+	+	-	-
<i>Stellaria imbricata</i> Bunge	+	+	+	-
<i>Atriplex altaica</i> Sukhor	+	+	+	-
<i>Limonium congestum</i> (Ledeb.) O. Kuntze	+	+	+	-
<i>Stelleropsis altaica</i> (Theib.) Pobed.	+	+	-	+
<i>Rhodiola algida</i> (Ledeb.) Fisch. et C.A. Mey	+	+	+	+
<i>Sibiraea laevigata</i> (L.) Maxim	+	+	-	+
<i>Astragalus burtschumensis</i> Saposhn. ex Sumn.	+	-	-	+
<i>Astragalus kurtshumensis</i> Bunge	+	-	+	+
<i>Astragalus majevskianus</i> Kryl.	+	-	+	+
<i>Astragalus pseudotesticulatus</i> Sancz. et Ulzj	+	-	+	-
<i>Astragalus scleropodus</i> Ledeb.	+	-	-	+
<i>Astragalus xanthotrichus</i> Ledeb.	+	-	-	+
<i>Astragalus zaissanensis</i> Sumn.	+	-	+	+
<i>Oxytropis martjanovii</i> Kryl.	+	+	+	-
<i>Craniospermum subfloccosum</i> Kryl.	+	+	+	+
<i>Mertensia pallasii</i> (Ledeb.) G. Don fil.	+	+	-	+
<i>Mertensia tarbagataica</i> B. Fedtsch	+	-	-	+
<i>Euphrasia schischkinii</i> Serg.	+	+	+	+
<i>Pedicularis abrotanifolia</i> Bieb. ex Steven	+	+	+	+
<i>Pedicularis altaica</i> Bieb. ex Steven	+	+	+	+
<i>Dracocephalum bungeanum</i> Schischk. et Serg.	+	+	+	-
<i>Laphanthus krylovii</i> Lipsky	+	+	+	+
<i>Nepeta densiflora</i> Kar. et Kir.	+	-	+	+
<i>Panzeria canescens</i> (Bunge) Sojak.	+	+	+	-
<i>Iris kamelinii</i> Alexeeva	+	+	-	-
<i>Gagea kuraiensis</i> Levichev	+	+	-	-
<i>Elymus karakabiensis</i> Kotukh.	+	+	-	+
<i>Poa vereschaginii</i> Tzvel.	+	+	-	+
<i>Stipa sczerbakovii</i> Kotukh	+	-	-	+

Note: + existent species, - absent species

These species are distributed in China and Kazakhstan, but their area is not limited to Altai Mountains. The following species listed in Table 2 may be attributed to this group, such as *Fritillaries pallidiflora* Schrenk (Red Data Book of Kazakh SSR, 1981; Ivaschenko, 2005), *Fritillaria wahjewisii* Regel (Wu, 1994–2005), *Gymnospermium altaicum* (Pall.) Spach (Red Data Book of Kazakh SSR, 1981; Red Data Book of Altaiskiy krai, 2006), *Trapa zaissanica* (Fler.) V. Vassil. (Wu, 1994–2005), *Polygonum glaresum* Scischk. *P. schischkinii* Ivanova ex Borodina (Wu, 1994–2005;

Borodina, 1989) and *Saussurea involucreata*. Their distribution is in 2 or 3 countries, but all their locations are within Altai Mountains. Thus, being near endemic in their countries may be attributed to A(iv), 31 species of Altaic endemics, listed in Table 2 may be also considered as national sub-endemics and can be added to the list of the threatened species of Xinjiang.

As for the groups of species under protection in Xinjiang, some of them distributed widely, but their limited distribution lies within the Northern flanks of China or in Chinese Altai. The limited distribution

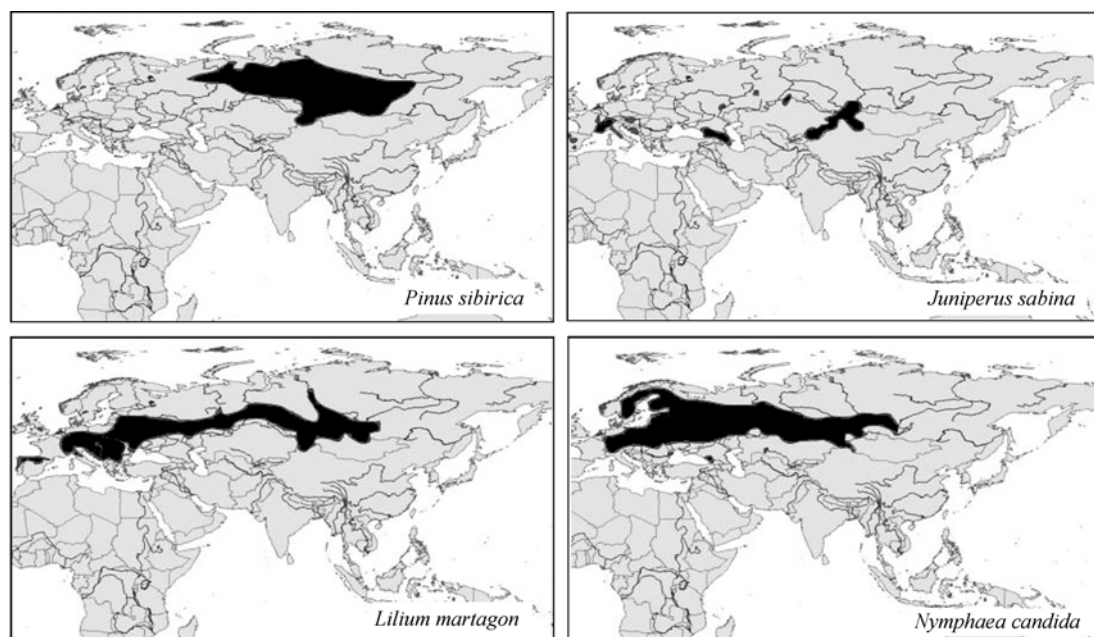
Table 2 The threatened plant species of Altai region in Xinjiang

Species	Species	Species
<i>Abies sibirica</i> Ledeb.	<i>Erigeron songaricus</i> Y.We i et Z.X. An	<i>Nymphaea candida</i> C.Presl.
<i>Adonis villosa</i> Ledeb.	<i>Erythronium sibiricum</i> (Fisch. et Mey.) Kryl	<i>Oxalis acetosella</i> L.
<i>Adoxa moschatellina</i> L.	<i>Fritillaria pallidiflora</i> Schrenk	<i>Phyllodoce caerulea</i> Babington
<i>Alisma nanum</i> D.F.Cui	<i>Fritillaria walujewii</i> Regel	<i>Picea obovata</i> Ledeb.
<i>Allium altaicum</i> Pall.	<i>Gentiana algida</i> Pall.	<i>Pinus sibirica</i> Du Tour.
<i>Astragalus penduliflorus</i> Lam.	<i>Gymnocarpium altaicum</i> C.Y. Yang	<i>Polygonum glareosum</i> Scischk
<i>Atraphaxis jrtyschensis</i> C.Y. Yang et Y.L. Han	<i>Gymnospermium altaicum</i> (Pall.) Spach	<i>Populus nigra</i> L.
<i>Betula halophila</i> Chung ex P.C.Li	<i>Juniperus sabina</i> L.	<i>Pulmonaria mollissima</i> Kern.
<i>Circaea lutetiana</i> L.	<i>Leymus racemosus</i> (Lam.) Tzvel.	<i>Saussurea involucrata</i> (Kar. et Kir.) Bip.
<i>Daphne altaica</i> Pall.	<i>Lilium martagon</i> var. <i>pilosiusculum</i> Freyn.	<i>Sorbus sibirica</i> Hedl.
<i>Delphinium eglandulosum</i> C.Y. Yang et B.Wang	<i>Megacarpaea megalocarpa</i> (Fisch. ex DC.) Fedtsch	<i>Tussilago farfara</i> L.
<i>Empetrum nigrum</i> L.	<i>Nuphar pumilum</i> (Hoffm.) DC.	

made them vulnerable and (or) rare. Special protection measures are needed to ensure their longer-term survival in the area. This is why we should support the suggestion of adding the A (v) category (Artemov *et al.*, 2007); and the other 19 species should be included to the list.

Phyllodoce caerulea Babington is arctoalpine species. In spite of being distributed both in Eurasia and America, it is quite rare on the southern part, and only penetrates into the Altai Mountains of Chinese territory. *Abies sibirica* Ledeb., *Erythronium sibiricum* (Fisch. et Mey.) Kryl., *Picea obovata* Ledeb. and *Pinus sibirica* Du Tour. (Siberian boreal species and being a part of sub-arctic conifer forests) are rare and

vulnerable in China (Fig. 2). Boreal species *Adoxa moschatellina* L., *Sorbus sibirica* Hedl., *Empetrum nigrum* L., *Oxalis acetosella*, *Lilium martagon* var. *pilosiusculum* Freyn, *Nuphar pumila* are quite broad Eurasian distribution and occur in China both in the NW (Altai) and NE, together with conifer forests. Contrasted with them, *Nymphaea candida* C. Presl and *Populus nigra* L. do not propagate too far to the East. *Nymphaea candida* has some isolated locations in the Eastern Siberia, whereas *Populus nigra* does not occur in the East of Yenisyw River at all. The range of Eurasian *Juniperus sabina* L. is fragmented, and the southeast limit of its distribution is in the Chinese Altai as well (Hultén, 1986).

**Fig. 2** Geographical distribution of *Pinus sibirica*, *Juniperus sabina*, *Lilium martagon* and *Nymphaea candida*

Stemmacantha carthamoides Wild. is distributed in Siberia, Kazakhstan, Xinjiang of China and Mongolia. It has been declared to be vulnerable in China, Russia and Kazakhstan, and has been included in the national Red Data books (Red Data Book of Kazakh SSR, 1981; Red Data Book of Altai Republic, 1996; Red Data Book of Russian Federation, 2008) and regional Red Data book (Red Data Book of Altaiskiy krai, 2006). Other valuable medicinal (*Adonis villosa* Ledeb.) and food (*Allium altaicum* Pall.) plants with restricted distributions are included in the Red data books of Altai Republic and Altaiskiy krai as vulner-

able and endangered species.

The distribution of some of the species is sufficiently fragmented into ranges in the Altai territory, which are considered to be relics like *Daphne altaica* Pall. (Red Data Book of Kazakh SSR, 1981; Red Data Book of Altai Republic, 1996; Red Data Book of Russian Federation, 2008), *Circaea lutetiana* L. (Polozhiy, 1985; Krapivkina, 1985), *Saussurea involucrata* (Kar. et Kir.) Bip. (Red Data Book of Kazakh SSR, 1981). The investigations show that almost 71 species recorded from the Chinese Altai territory may be included into the category A (Table 3).

Table 3 The species of Chinese Altai Mountains attributed to criterion A

Criterion	Species	Criterion	Species
A iii	<i>Alisma nanum</i> D.F.Cui	A iv	<i>Circaea lutetiana</i> L.
A iii	<i>Atraphaxis jrtyschensis</i> C.Y. Yang et Y.L. Han	A iv	<i>Craniospermum subfloccosum</i> Kryl.
A iii	<i>Atriplex altaica</i> Sukhor.	A iv	<i>Daphne altaica</i> Pall.
A iii	<i>Delphinium eglandulosum</i> C.Y. Yang et B.Wang	A iv	<i>Delphinium inconspicuum</i> Serg.
A iii	<i>Erigeron songaricus</i> Y.Wei et Z.X. An	A iv	<i>Dracocephalum bungeanum</i> Schischk. et Serg.
A v	<i>Abies sibirica</i> Ledeb.	A iv	<i>Elymus karakabiensis</i> Kotukh
A v	<i>Adonis villosa</i> Ledeb.	A iv	<i>Empetrum nigrum</i> L.
A v	<i>Adoxa moschatellina</i> L.	A iv	<i>Erigeron altaicus</i> M.Pop.
A v	<i>Erythronium sibiricum</i> (Fisch. et Mey.) Kryl.	A iv	<i>Euphrasia schischkinii</i> Serg.
A v	<i>Gentiana algida</i> Pall.	A iv	<i>Fritillaria pallidiflora</i> Schrenk
A v	<i>Juniperus sabina</i> L.	A iv	<i>Fritillaria walujewii</i> Regel.
A v	<i>Laphanthus krylovii</i> Lipsky.	A iv	<i>Gagea kuraiensis</i> Levichev
A v	<i>Leymus racemosus</i> (Lam.) Tzvel.	A iv	<i>Gymnocarpium altaicum</i> C.Y. Yang
A v	<i>Lilium martagon</i> var. <i>pilosiusculum</i> Freyn.	A iv	<i>Gymnospermium altaicum</i> (Pall.)Spach.
A v	<i>Nuphar pumilum</i> (Hoffm.)DC.	A iv	<i>Iris kamelinii</i> Alexeeva
A v	<i>Nymphaea candida</i> C.Presl	A iv	<i>Limonium congestum</i> (Ledeb.) O. Kuntze
A v	<i>Oxalis acetosella</i> L.	A iv	<i>Mertensia pallasii</i> (Ledeb.) G. Don fil.
A v	<i>Phyllodoce caerulea</i> Babington	A iv	<i>Mertensia tarbagataica</i> B.Fedtsch.
A v	<i>Picea obovata</i> Ledeb.	A iv	<i>Mesostemma martjanovii</i> (Kryl.) Ikonn.
A v	<i>Pinus sibirica</i> Du Tour	A iv	<i>Nepeta densiflora</i> Kar. et Kir.
A v	<i>Populus nigra</i> L.	A iv	<i>Oxytropis martjanovii</i> Kryl.
A v	<i>Pulmonaria mollissima</i> Kern.	A iv	<i>Panzeria canescens</i> (Bunge)Sojak.
A v	<i>Sorbus sibirica</i> Hedl.	A iv	<i>Pedicularis abrotanifolia</i> Bieb. ex Steven
A v	<i>Tussilago farfara</i> L.	A iv	<i>Pedicularis altaica</i> Bieb. ex Steven
A v	<i>Abies sibirica</i> Ledeb.	A iv	<i>Poa veresczaginii</i> Tzvel.
A v	<i>Adonis villosa</i> Ledeb.	A iv	<i>Polygonum glareosum</i> Scischk
A v	<i>Adoxa moschatellina</i> L.	A iv	<i>Ptarmica ledebourii</i> (Heimerl.)Serg.
A iv	<i>Allium altaicum</i> Pall.	A iv	<i>Pyrethrum alatavicum</i> (Herd.)O. et B. Fedtsch
A iv	<i>Astragalus burtshumensis</i> Saposhn. ex Sumn.	A iv	<i>Rhodiola algida</i> (Ledeb.) Fisch. et C.A. Mey.
A iv	<i>Astragalus kurtshumensis</i> Bunge.	A iv	<i>Saussurea involucrata</i> (Kar. et Kir.)Bip.
A iv	<i>Astragalus majevskianus</i> Kryl.	A iv	<i>Sibiraea laevigata</i> (L.) Maxim
A iv	<i>Astragalus penduliflorus</i> Lam.	A iv	<i>Stellaria imbricata</i> Bunge.
A iv	<i>Astragalus pseudotesticulatus</i> Sancz. et Ulzij.	A iv	<i>Stelleropsis altaica</i> (Theib.)Pobed.
A iv	<i>Astragalus scleropodus</i> Ledeb.	A iv	<i>Stemmacantha carthamoides</i> Willd.
A iv	<i>Astragalus xanthotrichus</i> Ledeb.	A iv	<i>Stipa sczerbakovii</i> Kotukh
A iv	<i>Astragalus zaissanensis</i> Sumn.	A iv	<i>Trapa zaissanica</i> (Fler.)V.Vassil.
A iv	<i>Betula halophila</i> Chung ex P.C.Li		

3.2.2 The species of Criteria B and C

Following the recommendations for identifying IPA (Anderson, 2002), to qualify as an IPA needs to satisfy one or more of the aforementioned criteria (A, B and C). Based on the results of the mentioned above, there are a lot of original and rich species in Chinese Altai Mountains, which may be qualified as an IPA in accordance with criteria B and C. Criterion B is supposed to have an exceptionally rich flora in a European context in relation to its bio-geographic zone. The areas that satisfy to the criterion C are outstanding examples of habitat types, of the global or European plant conservation and botanical important (Anderson, 2002). The dark conifer forests of Chinese Altai, composed of *Pinus sibirica*, *Abies sibirica* and *Picea obovata* with numerous herbaceous boreal species, may be qualified as habitats, satisfied to criterion C. In accordance with classification, accepted by European Nature Information System (2004), which were transformed from Altai-Sayan region (Artemov *et al.*, 2007), these plant communities should be attributed to the type G3.1.–dark conifer forests with predominated *Abies*, *Picea* and *Pinus sibirica*. These communities are common for Siberia, but many botanists considered them to be very rare in Xinjiang and other regions of China (Qian *et al.*, 1956; Hou, 1982). These sites in the Chinese Altai are on their southern border of distribution. Being rare, these species need special conservation measures.

Nevertheless, careful search of plant lists, included in the Red Data Books of adjacent territories, and their distribution, allows to assume that the Chinese list of rare plants (particularly, Chinese Altai) is not comprehensive and new rare species may be revealed on the frontier territories. It should be taken into consideration that Chinese part of Altai Mountains System, as well as Kazakhstan, are situated within the Altai-Dzungarian floristic province, which is known to be the richest in species diversity. On the frontiers between China and Kazakhstan, Tarbagatai, Saur, Zaissan and Markakol-Kanas floristic regions are known to be the richest in endemics in Kazakhstan Altai. This means that variety of floristic resources of

this territory has not been sufficiently explored yet, and more detailed investigations are needed to record the endemic species from both the whole Altai Mountains and the Chinese Altai Mountains.

4 Conclusions and suggestion

In the paper, we critically reviewed the plant species in the Chinese Altai Mountains and classified 71 species into category A. The Chinese Altai territory, a place of high botanical and aesthetic value needs special protection measures for long-term research and conservation. The following recommendations should be taken into account for this purpose:

- (1) Reveal the plant diversity in the frontier territories.
- (2) Identify IPA based on criteria A (threatened species), B (botanical richness) and C (threatened habitats).
- (3) Monitor the selected areas in specified states.
- (4) Introduce sustainable use of plant resources.
- (5) Promote education and awareness about plant diversity, endemism and traditional uses.

These measures are necessary for the protection of Altai biodiversity because of the intensification of human activities. And it may be considered as a step to fulfill the national obligations implied under the purview of Convention on Biological Diversity. The 71 species from Chinese Altai Mountains could be attributed to the criterion A. The dark conifer forests of Chinese Altai, composed by *Pinus sibirica*, *Abies sibirica* and *Picea obovata* with numerous herbaceous boreal species, satisfy the criterion C. As for criterion B, it concerns the area with the highest biodiversity, and the list of these species need a very detailed search of territory. Therefore the area can not be recommended, only based on our present-day data.

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