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The genus *Trollius* (Ranunculaceae) in the Russian Far East

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Summary. The critical revision of *Trollius* L. (Ranunculaceae) in the Far East of Russia was made, in which nine species were recognized. The identification key and taxonomical synopsis of the genus have been provided. Synonymy, geographical distribution and coeno-ecological peculiarities of each species of these nine species are presented. For the first time *Trollius japonicus* Miq. was found in the territory of Russia (the Kurile Islands: Iturup, Kunashir). Furthermore, we found that the information on the distribution of this species on Sakhalin Island is wrong owing to the incorrect identification. The information about the medical use of each of nine *Trollius* species is also provided.

Род *Trollius* (Ranunculaceae) во флоре российского Дальнего Востока

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Ключевые слова: Дальний Восток России, распространение, таксономия, Ranunculaceae, *Trollius*.

Аннотация. Критическая ревизия рода купальница (*Trollius* L., Ranunculaceae) флоры Дальнего Востока России позволила выявить девять видов. Составлен ключ для определения видов и их таксономический контекст. Приводится синонимика, географическое распространение и эколого-ценотические особенности таксонов. Впервые для России (Курильские о-ва: Итуруп и Кунашир) приведен *Trollius japonicus* Miq. Показано, что ранее известные сведения о распространении этого вида на о-ве Сахалин основаны на неверной идентификации образцов. Изложены сведения об использовании видов *Trollius* в качестве лекарственных растений.

Introduction

The genus *Trollius* includes c. 35 species distributed in the extra-tropical regions of Northern Hemisphere. In Russia about 19–20 species are recognized. *Trollius ledebourii* Reichenb. is used in folk medicine to treat epilepsy (Vostrikova, 1973); *T. chinensis* Bunge has antibacterial (Lin et al., 2001; Lu et al., 2015), antiviral (Li et al., 2002; Cai et al., 2006) antioxidant and antitumor (Song et al., 2013; An et al., 2015) effects. Other species of the genus can also be used for medicinal purposes.

The territory of the Russian Far East contains 6 species (Woroschilov, 1982) or 8 species of *Trollius* (Luferov, 2004). Based on Woroschilov (1982), the territory of the Far East is characterized by monsoon climate and does not include the West of the Amur region, the Khabarovsk territory, and Arctic and subarctic areas of the Magadan region and the Chukotka Peninsula. Luferov (1995, 2004) considered the Russian Far East as its administrative boundaries, which is also the floristic zoning scheme suggested by S. Kharkevich (1985).

Species of the genus *Trollius* are perennial herbs with short rhizomes and numerous adventitious roots, simple or branched hollow stems. At the base of aboveground shoots, there are scale-like leaves and fibrous remnants of leaf petioles. Photophilic leaves are palmatipartite or palmatisecte and their margins are scallop-serrate or cut-serrate. Flowers are solitary or assembled in a monochasium inflorescence, termed gyrus. Calyx is corolla-shaped. Sepals have 5 to 20–30; different species have orange, yellow, lemon yellow, almost white or creamy white. Petals amount to 5–20 in number; they are linear, lanceolate, lobed, or obovate, and nectarous fossa at the base. The ovary is unilocular. Ovules are arranged linearly. The fruit is multifolliculus and opens from the ventral side.

The main problem of taxonomic study of *Trollius* is that the diagnosis of species usually rests upon the peculiarities of the structure of flowers. Structural features of vegetative organs and fruits were paid less attention. Besides, a small number of distinctive features were taken into account and little attention was paid to the variability of plants collected in different habitats and their different parts.

With the view to determine species and subspecies we used a set of structural characteristics of vegetative and generative organs: height of above-soil shoot; shape, sizes and degree of dismemberment of leaf blades; shape, sizes and number of sepals, petals, stamina, the ratio of their lengths; sizes and number of fruitlets; length of stylodia and other features (Siplivinsky, 1972; Doroczewska, 1974; Kadota, 1987; Luferov, 1995).

The main aim of this work was to study the taxonomy and characteristics of the *Trollius* species in the flora of the Russian Far East. We first identify morphological characters of the *Trollius* species of the Far East as diagnostic ones, make up the key for identifying species, and analyze the distribution of *Trollius* species in Far East of Russia. The importance of the undertaken research can be seen both in getting to know the biodiversity of this genus in the Russian Far East and in the practical relevance of its representatives as sources of biologically active compounds.

Methods

In this study, we followed the Russian Far East within its administrative borders, including the Amur, Kamchatka, Magadan, Sakhalin Regions, Khabarovsk and Primorsky Territories. Morphological and geographical methods of the research have been used. The specimens deposited in the following herbarium collections: V. L. Komarov Botanical Institute (LE), the Main Botanical Garden (MHA), M. V. Lomonosov Moscow State University (MW), Institute of Biology and Soil (VLA), were examined. Meanwhile, living plants were also collected during 10 expeditions (1980, 1986–1993, 2015) in the Sakhalin Region (Sakhalin Island, the Islands of Iturup and Kunashir), and Khabarovsk and Primorsky Territories.

Results and discussion

Diagnostic keys published earlier (Schipczinsky, 1937; Siplivinsky, 1972; Doroczewska, 1974; Woroschilov, 1982) fail to cover all currently known species of *Trollius*. An updated version of the identification key of the Far Eastern representatives of the genus has been suggested. The key has been

suggested for their determination based on the analysis of morphological characters of vegetative and generative organs: height of the aerial shoots, number of flowers on one shoot, the degree of dissection of the leaves and their segments, the number, shape, size and coloration of the elements of the perianth, the ratio of length of the sepals, petals and stamens; the number and size of fruitlets, the length of beaks (Luferov, 1991, 1995, 2004).

1. Petals (nectaries) 1.5–2 times longer sepals (Fig. 1A) 1. *T. chinensis* subsp. *macropetalus*
– Petals (nectaries) shorter than sepals, may be almost equal to them 2
2. Petals (nectaries) 1.5–2 times as long as stamens. Follicles 10 mm long. Beaks 1.5 mm long (Fig. 1B) 2. *T. ledebourii*
– Petals (nectaries) shorter than stamens by 1–8 mm, equal to them or by 2–4 mm longer than them 3
3. Petals (nectaries) as long as stamens, may also be 1–3 mm longer or shorter than stamens 4
– Petals (nectaries) twice as short as stamens 6
4. Sepals 5–7 in number, rarely up to 11. Petals (nectaries) linear, with a slightly dilated and rounded apex 5
– Sepals 9–12 in number. Petals (nectaries) are of a different shape 7
5. Leaf blades orbicular-pentagonal, 4–8 cm long and 5–10 cm wide, serrate-dentate with triangular sharp teeth. Flowers solitary, rarely arranged by 2 or 3, 3–4 cm in diameter. Sepals orange-yellow or yellow. Petals (nectaries) reddish-orange, equal to the stamens or 1–3 mm longer. Follicles have arcuate flexible 2–3 mm long beaks (Fig. 1D) 4. *T. riederianus*
– Leaf blades rounded and reniform, 8–14 cm long. 10–24 cm wide, serrated with narrow triangular pointed denticles. Flowers arranged by 2 (rarely) or 3–7, 2.5–3.5 cm in diameter. Sepals light yellow or yellow-orange. Petals (nectaries) orange, shorter than stamens by 1–3 mm. Follicles straight or slightly arcuate, with more long (3–4.5 mm), thin, easily breaking beaks (Fig. 1F) 6. *T. japonicus*
6. Plants are (20) 30–40 cm tall. The stem is non-branching, with 1 flower. Sepals sulphur-yellow. Petals (nectaries) narrowly linear, acute, 1–3 mm longer than the stamens. Pedicels up to 10 cm long, when with fruits they become 20 cm long (Fig. 1C) 3. *T. sibiricus*
– Plants (20) 70–120 cm tall. The stem branching, with 2–5 flowers, occasionally non-branching. Sepals orange-yellow or yellow. Petals (nectaries)

obovate or spatulate, obtuse, equal in length to stamen filaments. Pedicels 2–5 cm long, when with fruits, they become 10 cm long (Fig. 1G)

- 7. *T. miyabei*
7. Plants bloom prior to the development of leaves. Sepals white or pale cream. Follicles up to 25 mm long. Beaks 8–18 mm long, equal to or exceeding the length of the ovary; thin, straight or slightly curved (Fig. 1I) 9. *T. chartosepalus*
– Plants bloom when leaves developed. Sepals yellow. Beaks several times shorter than the ovary, more or less thickened 8
 8. Sepals 5–6 in number. Beaks up to 1.4 mm long, subulate, straight or slightly curved (Fig. 1E) 5. *T. uniflorus*
– Sepals 9–12 in number. Beaks about 2 mm long, membranous and laterally flattened, arcuately curved (Fig. 1H) 8. *T. membranostylis*

Gen. 1. *Trollius* L. 1753, Sp. Pl. 1: 556. Type: *T. europaeus* L.

About 35 species distributed in extratropical regions of the Northern Hemisphere.

Subgen. 1. *Trollius* – Flowering shoots apical. The inflorescence cymose or flowers solitary. Basal leaves (or just a leaf) arranged in rosettes. Stem leaves sessile or petiolate. Rhizomes branching and ascending. Type: *T. europaeus* L.

Sect. 1. *Longipetala* Dorosz. 1974, Monogr. Bot. (Warszawa), 41: 159. – Petals (nectarines) linear, flat, thin, longer than sepals or nearly equal to them. Type: *T. asiaticus* L.

1. *T. chinensis* Bunge, 1831, Enum. Pl. Chin. Bor.: 3. – *T. macropetalus* (Regel) Fr. Schmidt, 1868, Mém. Acad. Sci. Pétersb. (Sci. Phys.-Math.), sér. 7, 12, 2 (Reisen Amur-Lande und Sachal.): 88. – *T. asiaticus* L. var. *chinensis* (Bunge) Maxim. 1889, Enum. pl. Mong. 1: 25. – *T. ledebourii* auct., non Reichenb.: Kom. 1903, Acta Horti Petropol. 22, 1 (Fl. Manch. 2, 1): 230.

Amur Region (South), Sakhalin (South-West), Primorsky Territory. – Forest edges, clearings of broadleaf and coniferous-broadleaf forests, wet meadows on hills and floodplains. General distribution: China: North and Northeast China; Korea Peninsula. – Described from Northern China. Syntype: “China. 1831, [fl.], d[ed]. Bunge” (LE!).

The typical subspecies of *T. chinensis* subsp. *chinensis* grows in Northern and North-Eastern China; with 8–12 sepals and sharp petals up to 25 mm long, narrowed at the top. In the East of the species range

(Russian Far East, Korean Peninsula, East of Manchuria) *T. chinensis* subsp. *macropetalus* (Regel) Lufarov (1991, Bull. Mosc. Soc. Nat., Biol. 96, 5: 74) is usually common; it is distinguished by 5–7 sepals. Petals are up to 35 mm long, gradually tapering at the top (Lufarov, 1991, 1995).

2. *T. ledebourii* Reichenb. 1825, Icon. Bot. Crist. 3: 63, tabl. 272.

Amur Region, Khabarovsk Territory, Jewish Autonomous Region, Primorsky Territory. – On the upland and floodplain meadows, among shrubs, at forest edges and clearings, in the mountains. General distribution: Eastern Siberia; Northern and North-Eastern China. – Described from Siberia. Type: Icon. Bot. Crist. 3: 63, tabl. 272.

3. *T. sibiricus* Schipcz. 1923, Bot. mat. (Petrograd), 4, 2: 11. – *T. boreosibiricus* Tolm. 1971, Arct. flora USSR, 6: 136, nom. superfl.

Khabarovsk Territory. – Meadows, river valleys, swamp margins, in sparse forests on hills, on rocky slopes and cliffs, up to high mountainous belt, often on outcrops of limestone. General distribution: Eastern Siberia. – Described from Siberia. Lectotype: “Valley of the Lena River, Bulun (from Yakutsk 1615 miles). 3 VII 1914, V. A. Kashkarov” (LE!).

Sect. 2. *Insulaetrollius* Dorosz. 1974, Monogr. Bot. (Warszawa), 41: 160. – Petals (nectaries) oblong-elliptic, spatulate or pear-shaped, equal in length to the stamens, shorter or slightly longer than them. Type: *T. riederianus* Fisch. et Mey.

4. *T. riederianus* Fisch. et Mey. 1837, Index Sem. Horti Bot. Petropol. 4: 48; Schipczinsky, 1937, Fl. USSR, 7: 50, p.p. – *T. kurilensis* Sipl. 1972, Novitates systematicae plantarum vascularium, 9: 177. – *T. uncinatus* Sipl. 1972, Novitates systematicae plantarum vascularium, 9: 174, p.p.

Amur Region, Kamchatka Peninsula, Commander Islands, Sakhalin Region (Kurile Islands), Khabarovsk Territory, Primorsky Territory. – On the upland and floodplain meadows, forest edges, clearings; on plains and on hills, in mountains, on grass-covered and rocky graveled slopes, rocks. General distribution: Eastern Siberia; North America (The Aleutian Islands). – Described from the Kamchatka Peninsula. Type: “Kamtschatka, Rieder. Cult. in horti Petropol., 1837, Fisch. et Mey.” (LE!).

In the West and South-West of area subspecies *T. riederianus* Fisch. et Mey. subsp. *uncinatus* (Sipl.) Lufarov (1991, Bull. Mosc. Soc. Nat., Biol. 96, 5:

75) is distributed, which is characterized by the following features: petals linear-spatulate, 1–3 mm shorter stamens. Typical subspecies (*T. riederianus* subsp. *riederianus*) has petals linear, apex slightly dilated, with 1–3(4) mm long stamens. Other characters specified V. N. Siplivinsky (1972: 175) for *T. uncinatus*: “the smaller size of all parts” and “form of leaflets”, in our opinion, do not have taxonomic value.

Area of *T. riederianus* subsp. *uncinatus*: Eastern Siberia (Buryatia, Chita Region, Yakutia), Far East (north of Amur Region, Khabarovsk Region: Bureinsky mountain range, the northern Sikhote-Alin).

5. *T. uniflorus* Sipl. 1972, Novitates systematicae plantarum vascularium, 9: 178.

Amur Region, Khabarovsk Territory, Sakhalin, Primorsky Territory. – In meadows, from lowlands to high mountain zones, and also in light forests of mountainous massifs, on the gravel banks of streams, stony slopes, outcrops of limestone. General distribution: The Eastern Siberia. – Described from Khabarovsk Territory. Type: “The lower Amur Region, bass. River Limury, on a high mountain plateau near a stream. 16 VI 1934. N. N. Zinger” (LE!).

6. *T. japonicus* Miq. 1867, Ann. Mus. Bot. Lugd.-Batav. 3: 6; Miyabe, 1943, Acta Phytotax. Geobot. (Kyoto), 13: 12; Ohwi, 1965, Fl. Jap.: 459. – *T. miyabei* non Sipl.: Kadota, 1987, Bull. Natn. Sci. Mus., Tokyo, ser. B, 13 (3): 118, p.p.

The Kuril Islands: Iturup, Kunashir. – In wet meadows, swamp margins, deciduous and mixed forests, forest clearings and edges, along rivers and streams, grass-covered pebbles. – Described from Japan. Type: “Japonia, Jeso, s.a. Siebold” (L).

The indication of *T. japonicus* (Schipczinsky, 1937) for the Island of Sakhalin is incorrect (Voroshilov, 1982). The presence of this species in the Kuril Islands (Vorobiev, 1974) was not confirmed by herbarium specimens. It was noted that the plants from the southern Kuril Islands exhibit similarities with *T. japonicus* (Siplivinsky, 1972; Barkalov, 2009): for example, on Bogdan Khmel'nitsky Volcano (Barkalov, 2009).

We confirm that reliable samples of this species were collected in the southern Kuril Islands: Iturup, Kunashir.

Russia: “Isl. Iturup, Bay Sentyabrskiy, slope of the sea terrace, southern exposure on the rock, № 801, 14 VI 1968. Seledets” (VLA!). – «О-в Итуруп, бухта Сентябрьская, склон морской террасы, южн.[ая] экспозиция, на скале, № 801, 14 VI 1968. Селедец» (VLA!).

Russia: "Isl. Iturup, Bay Zolonetz, on the banks of the creek, № 803, 15 VIII 1968. Seledets" (VLA!). – «О-в Итуруп, бухта Золонец, на берегу ручья, № 803, 15 VIII 1968. Селедец» (VLA!).

Russia: "The Kuril Islands, Kunashir, in the vicinity of Yuzhno-Kurilsk, on the track to Lake Lagunnoe, in the marsh, 31 VII [19] 83, № 8. M. G.

Pimenov, E. V. Kljuykov" (MW!). – «Курильские о-ва, Кунашир, окр. г. Южно-Курильска, по дороге на оз. Лагунное, на болоте, 31 VII [19] 83, № 8. М. Г. Пименов, Е. В. Ключков» (MW!).

7. *T. miyabei* Sipl. 1972, Novitates systematicae plantarum vascularium, 9: 176. – *T. schipczinskyi*



Fig. 1. Flowers of *Trollius*:

- A. *T. chinensis* Bunge subsp. *macropetalus* (Regel) Luferov (photo by V. V. Yakubov).
 B. *T. ledebourii* Reichenb. (photo by V. V. Yakubov).
 C. *T. sibiricus* Schipcz. (photo by G. Chulanova).
 D. *T. riederianus* Fisch. et Mey. (photo by V. V. Yakubov).
 E. *T. uniflorus* Sipl. (photo by G. Chulanova).
 F. *T. japonicus* Miq. (photo by A.V. Semenov).
 G. *T. miyabei* Sipl. (photo by V. Yu. Barkalov).
 H. *T. membranostylis* Hult. (photo by V. Yu. Barkalov).
 I. *T. chartosepalus* Schipcz. (photo E. Andriyanova and O. Vokhmina).

Miyabe, 1943, Acta Phytotax. Geobot. (Kyoto), 13: 14, p.p., nom. superfl. – *T. japonicus* auct. non Miquel: Schipczinsky, 1937, Fl. USSR, 7: 50, p.p. – *T. altaicus* C. A. Mey. subsp. *sachalinensis* Kadota, 1991, Mem. Natn. Sci. Mus., Tokyo, 24: 57, p.p. – *T. pulcher* auct. non Makino: Voroshilov, 1982, Opred. rast. soviet. Daln. Vostoka: 261, p.p.

Sakhalin. – Wet meadows, swamp margins, deciduous and mixed forests, forest clearings and edges, along rivers and streams, grass-covered pebbles. – Endemic. – Described from Sakhalin Region. Type: “South Sakhalin, Szujskiy Ridge, the surrounding area of Yuzhno-Sakhalinsk, the slope of the Mountain Chekhov, 800 m a. s. l., along the mountain creek. 22 VII 1948. M. Popov” (LE!).

Subgen. 2. *Acaulitrollius* Ziman, 1985, Morphology and phylogeny of the family Ranunculaceae: 203. – Flowering shoots axillary. Flowers solitary. Basal leaves arranged in rosettes. Stem leaves absent or few in number. Rhizome plain and vertical. Lectotype: *T. acaulis* Lind.

Sect. 1. *Pumilotrollius* Doroszcz. 1974, Monogr. Bot. (Warszawa), 41: 158. – The main shoot monopodial for a long time. Flowering shoots axillary, with 1–2 flowers. Sepals yellow, white or cream. Petals (nectaries) obovate or spatulate, two times shorter than the stamens. Type: *T. pumilus* Don.

8. *T. membranostylis* Hult. 1928, Kungl. Svensk. Vet. Akad. Handl., ser. 3, 5, 2 (Fl. Kamtch. 2): 99. – *T. schipczinskyi* Miyabe, 1943, Acta phytotax. geobot. (Kyoto), 13: 14, p. p., nom. superfl. – *T. riederianus* auct. non Fisch. et Mey.: Schipczinsky, 1937, Fl. USSR, 7: 50, p. max. p.

Chukotka Autonomous Area, Kamtchatka, Magadan Region, Khabarovsk Territory. – Tundra, from coastal lowlands to high mountainous belt, nival lawns, grass-covered graveled areas along rivers and streams, rocky slopes, rocks. – Endemic. –

Described from Khabarovsk Territory. Type: “Prope Ajan, legit Dr. Tiling” (LE!).

9. *T. chartosepalus* Schipcz. 1923, Bot. mat. (Petrograd), 4, 2: 11. – *Hegemone chartosepala* (Schipcz.) Khokhr. 1977, Novitates systematicae plantarum vascularium, 14: 80.

Chukotka Autonomous Area, Magadan Region. – In damp lowland and mountain meadows, turf-covered graveled areas near streams, outcrops of limestone and rocks, near melting snow, in the tundra and in larch forests. General distribution: Eastern Siberia (Yakutia). – Described from the Magadan Region. Lectotype: “Terra Tschuktschorum, in ditione fl. Anadyr, a fluvio hoc septentrionem versus ripa. 3 VI 1869, № 2108. Leg. G. Maydell” (LE!).

Conclusion

The study presents the taxonomic and geographic characteristics of 9 species of *Trollius* (Ranunculaceae) in the Russian Far East. The suggested key is based on a combination of vegetative and productive morphological characters. For the first time on the territory of Russia (the Kuril Islands: Iturup, Kunashir) *Trollius japonicus* Miq. was recorded. It is shown that the previously known information on the distribution of this species on Sakhalin Island is based on incorrect identification. The data can be used for further studies of *Trollius* species as perspective medicinal plants.

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