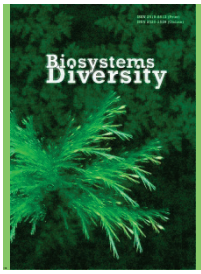

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Iris sibirica (Iridaceae) on the territory of Western Ukraine

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The state of *Iris sibirica* L. in the national botanical reserve "The Valley of the Irises" is characterized. In particular, it was found that *I. sibirica* should be classified in the group of Euro-West Siberian, and not as a Euro-Siberian or even Eurasian species. Phenological rhythms and peculiarities of fruiting have been studied. It is established that the duration of the vegetation period of *I. sibirica* lasts 187–246 days. The most important stages of the reproductive cycle of *I. sibirica* (structure of inflorescences, flowers, fruits and seeds, phenology, seed productivity) have been studied. We first discovered that on the inner surface of the flower tube there is a multilayer secretory tissue – perigonal nectar. The fruiting of *I. sibirica*, which lasts quite a long time: 2–3 months (60–80 days) from June to August, was studied. In this population two ways opening of the capsule were observed. *Apis mellifera* (Linnaeus, 1758) (honey bee) and *Bombus bombus* (Latreille, 1802) (bumblebee) are pollinators of *I. sibirica* in the reserve. The coefficient of seed productivity of *I. sibirica* was high and quite stable, but despite the high potential and actual seed productivity in the population there is a weak seed recovery, which is associated with high turfing and invasions of members of the phytophagous genus *Ceutorhynchus*. Their activity dramatically reduces the maturation and dissemination of full-fledged mature seeds due to damage to flowers, capsules and seeds in them. However, the population of *I. sibirica* in the "The Valley of the Irises" is mature, normal, with a slight predominance of young individuals, which provides it with positive dynamics.

Keywords: inflorescences; flowers; fruits; seeds; phenology; population; seed productivity.

Introduction

The genus *Iri*s Tourn. ex L. (*Iris*), which belongs to one of the most species-rich families in the class Monocotyledoneae – Iridaceae Juss., according to various sources, is represented in the world flora by from 250 (Mathew, 1981; Goldblatt & Manning, 2008) to 362 species and 16 subspecies (www.theplantlist.org).

In Ukraine, according to the latest list, there are 16 known taxa (Mosyakin & Fedoronchuk, 1999). The Red Book of Ukraine included only three of these taxa in 1996 – *Iris pontica* Zapał., *I. pineticola* Klokov, *I. pseudocyperus* Schur (Shelyag-Sosonko, 1996). In addition to the three mentioned, the third edition of the Red Book of Ukraine also includes *I. furcata* M. Bieb. and *I. sibirica* L. (Didukh, 2009).

All available data (herbarium collections, literature sources and the results of her own field research) on the distribution of these species were collected and analyzed in detail by Zhigalova (2012). The author came to the conclusion that the number of localities not only of rare and endangered species of the genus, but also of its widespread representatives, such as *I. pseudacorus* L., is declining (Zhigalova, 2014). However, the finding of a new population of *I. pseudacorus* in the steppe zone on the banks of the Luhansk River (Kharchenko, 2014) indicates that chorological studies of the genus Iris in Ukraine have not been completed.

Especially, this applies to their rare representatives, in particular *I. sibirica*. Thus, in Chernihiv Polissya, where, compared to other regions, there is a significant concentration of loci (over 30) of this species (Lukash, 2010; Podorozhny, 2012), a new locality of *I. sibirica* was found in the Dnipro-Desna interfluve (Shynder, 2013). In Chernivtsi region, of 20 previously known localities of *I. sibirica* only three were found by the authors to support this species (Tokaryuk et al., 2017). And the very recent finding of a large plot (20 hectares) in the Mykolayiv district of Lviv region came as a real surprise (Seniv & Tasenkevych, 2017).

Since the main studies of *I. sibirica* in Ukraine were conducted mainly on population level, the aim of our work was to study the most important stages of the reproductive cycle (structure of inflorescences, flowers, fruits and seeds, phenology, seed productivity), detect the major pests, reveal population density depending on microrelief conditions.

Materials and methods

The study was conducted in 2017–2019 on a population of *I. sibirica* in the vicinity of Naditychi, Mykolaiv district, Lviv region, on the floodplain terrace of the Dnister River, on a wet swampy meadow near the railway track (national botanical reserve "The Valley of the Irises "). Since the species is listed in the Red Book of Ukraine (Melnyk et al., 2009), the material was collected in the minimum amount required for the study.

The collected materials were fixed in a Chamberlain retainer. Microscopic examination was performed using a light microscope XS-2610 (PRC) and binocular microscope MBS-10, photographs were taken using a photography camera CANON IXUS 9515. Evaluation of seed productivity and population density was performed according to the method developed by Zlobin (2013) for 10 replicates. Phenological observations were performed according to the method of Beidemann (1974). Periodization of fruiting was studied according to the method of Levina (1963, 1967, 1970).

Results

On the territory of the reserve the inflorescence of *I. sibirica* produces a small-flowered (1–3 flowers) fan-shaped monochasium which is characterized by significant morphological polyvariance in number of flowers, their location in partial inflorescences and flowering order. Examining the population, we found that two-flowered and three-flowered inflorescences make up about 30%, four-flowered inflorescences about 15% and the least, six-flowered – 5% of inflorescences. In general, we found about 70% of five-flowered inflorescences.

The flowers in this population of *I. sibirica* are dark purple and pale purple (albino), large, 5–8 cm in diameter, apical, full, bisexual, three-membered, actinomorphic, with a lower ovary, on a long peduncle

(Fig. 1a). Examining the morphological structure of the flower, we found that the leaves of the perianth and stamens grow into a goblet-shaped inflated perianth tube 1.0–1.5 cm long (Fig. 2a). Examining the anatomical structure of the inner surface of the flower tube, we found a multilayered secretory tissue. The secretory epidermis of the nectar is represented by papillary cells with a thickened cuticle. The subepidermal layer of the nectar is small-celled with a dense cytoplasm, enriched with numerous small conducting bundles; such a nectar should be defined as perigonal mesophilic.

Palynological studies have revealed four types of pollen grain shapes: (1) broad- or (2) narrowly elliptical, (3) more or less narrowed to the tips, (4) sometimes elongated-pointed, with a wide seedling groove on the distal side of the grain. The size of pollen grains varies widely – 17.3–23.8 μm.

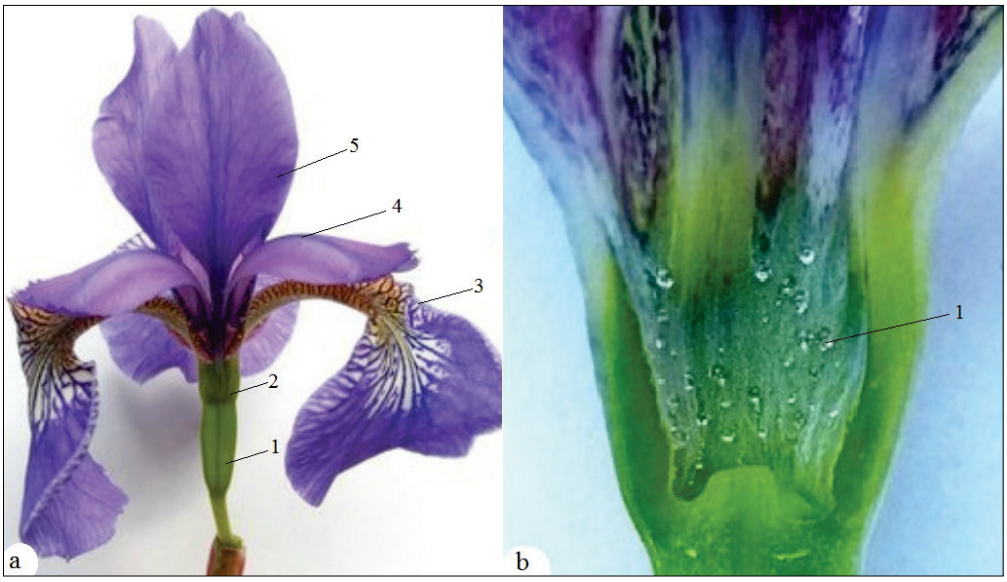

Fig. 1. Opened flower of *I. sibirica* (*a*): *1* – flower wreath, *2* – perianth tube, *3* – outer leaves of perianth, *4* – stylodium, *5* – inner leaves of perianth; longitudinal section through the the perianth tube (*b*): *1* – perigonal nectar

The *I. sibirica* fruit is a oblong-oval capsule, triangular at the apex, without a spout. The average length of the fruit is 26 mm, the diameter of the mature fruit is 14 mm. The size of the fruit depends on the number of seeds that ripen in the fruit. The number of seeds in one capsule can range from 7 to 206. The colour of the fruit at the beginning of fruiting is green, in the middle of fruiting – yellow, and at the end of fruiting – dark brown. The number of seed germs ranges from 222 to 340. The length of *I. sibirica* seeds is 4.6–4.8 mm and width 3.6 mm. The weight of 100 seeds varies in the range 0.17–0.19 g, in 1 g there are 11–14 pieces.

On the territory of the botanical reserve of national importance "The Valley of the Irises" we observed two ways of fruit opening. The first method is the opening along the dorsal vein, which is incomplete, often does not reach half the length of the ovary, and in low-seeded fruits barely reaches ¼ the length of the fetus. As a result of the divergence of the wings, the seeds in the upper part of the fetus are detached from the placenta and poured out. In the lower part of the fruit, the seeds remain in the nests of the ovary and fall out of them only when shaken. Often the seeds from the lower half of the capsule remain in it until the lodging and rot of generative shoots.

The second type of opening which we discovered is in the fruit, in which dorsal opening sutures are formed in the middle part of the fruit, and at the base and at the top they do not appear. The wings of the fruit do not diverge, but remain firmly connected to the central column, as a result of which the seeds are exposed from the capsule due to only one dorsal gap.

In the population of *I. sibirica*, we observed buds and flowers severely damaged by *Acklandia servadeii* (Séguy, 1933) (an iris fly) that winters in the soil and emerges in early spring to lay eggs in green buds. As a result, larvae hatch from the eggs, feed on the tissues of the buds and lay their excrement there. The bud inside begins to rot, and its perianth dries up. Flowers never bloom from such a bud.

In the fruits we found *Mononychus punctumalbum* (Herbst, 1784) (weevil), which lives near water bodies. Development occurs in the capsules of individuals of the genus *Iris*. Females lay eggs in the spring. The larvae develop quite rapidly and from late July to early September there is a new generation of adult *M. punctumalbum*. The bugs overwinter in the litter at the adult stage. It is established that the duration of the vegetation period of *I. sibirica* lasts 187–246 days. The growing season in the population begins with the formation of the first leaves and ends with their fall (Fig. 2). For *I. sibirica* the growing season strongly depends on weather conditions. Vegetation begins with the transition of average daily temperatures through the mark of + 5 °C, after which the curtain forms the first leaves 10–20 cm tall (Fig. 2a). Full leafing occurs with the formation of the curtain with leaves 70–100 cm tall (Fig. 2b). Budding in the population lasts 10–30 days, starting from the third decade of April to the third decade of May. Budding begins with the appearance of peduncles, which are formed in the axils of the leaves (Fig. 2c). Flowering of the population lasts 15–40 days – from the first decade of May to the third decade of June (Fig. 2d). The beginning of flowering occurs when the first bud is opened.

Fruiting of *I. sibirica* lasts a long time: 2–3 months (60–80 days), from June to August (Table 1). This period for one individual coincides in duration with the stage of budding and flowering. The beginning of fruiting is recorded by the fall of the perianth in the first flower, which occurs 7–10 days after wilting. During fruiting, the fruits change colour from green to yellow, then – to brown and black (Fig. 2e). Mass fruiting lasts 10–15 days. The end of fruiting, which was recorded by the fall of seeds into the soil, is in the second decade of August (Fig. 2f).

Table 1
Periodization of fruiting in *Iris sibirica* in 2017–2019

Periods	Duration, days
Duration of fruiting	60–80
Perianth wilting	7–10
Perianth precipitation	1
Mass fruiting	10–15
Browning of the fetus	10–15
Opening of a fruit	10

The average number of fruits per generative shoot in the study population ranges 2.2–3.0. The average number of seeds per generative shoot ranges 159–232, and the average number of seed germs per generative shoot – 222–340 pieces. The research results showed that the actual seed productivity is 71.7 pieces per capsule and the potential seed productivity is 106.6 pieces (Table 2). The coefficient of *I. sibirica* seed productivity, which characterizes the viability of the species in specific habitat conditions was high and fairly stable. Its values range from 66,8 %.

Fig. 2. Phenophases of *I. sibirica* 2017–2019: *a* – beginning of vegetation, *b* – complete leafing, *c* – budding, *d* – flowering, *e* – fruiting, *f* – dissemination

Fig. 3. Population density of *I. sibirica* in the plot 1 of the botanical reserve of national importance "The Valley of the Irises"

Since the territory of the botanical reserve consists of five plots with a total area of 20 ha, to study the population density we chose plot 1 as the main area, which is 13.8 ha in size (Fig. 3).

In this area, the species forms various mature clones (up to 50 generative shoots per individual in the adult mature state), gives significant self-seeding. Reproduction occurs both by seed and vegetatively. The area of the population is heterogeneous and we found places with fairly old clones, which have a density of 54 individuals per 100 m^2, and the number of generative shoots from 401 to 705 per 100 m^2. The main part of the area is formed by relatively young individuals, with a much higher density from 92 to 150 individuals per 100 m^2, respectively, and the number of shoots ranges from 8 to 1172 per 100 m^2.

Table 2
Indicators of *I. sibirica* seed productivity 2017–2019 (x ± SD, n = 10)

Indicators	Average value
Potential seed productivity, pcs.	106.6 ± 2.4
Actual seed productivity, pcs.	71.7 ± 3.5
Coefficient of seed productivity, %	0.668

Note: coefficient of seed productivity = actual seed productivity / potential seed productivity.

Discussion

I. sibirica is widespread in Europe: in France, in the north of Italy, in Switzerland, Austria, the Czech Republic, Slovakia, Germany, Hungary, Poland, Romania, Bulgaria, the countries of former Yugoslavia, in the north of Turkey, in Belarus, Estonia, Latvia, Lithuania Moldova, Ukraine, the European part of the Russian Federation; in Asia: Armenia, Azerbaijan, northwestern Kazakhstan, and southwestern Western Siberia (Tsvelev, 1979; Webb, 1980; Doronkin, 1987).

In some European publications (especially domestic ones, including the latest edition of the Red Book of Ukraine), which describe *I. sibirica*, the authors mistakenly include Eastern Siberia, the Far East, Japan, Mongolia, China and Korea in its range. In these areas, a completely different species is common – *I. sanguinea* Donn ex Hornem. (Doronkin, 1987; Yutang et al., 2000), which can be seen in the publication of Meusel et al. (1965). For this reason, the area of *I. sibirica* should be classified as Euro-West Siberian, and not as Euro-Siberian or even Eurasian type.

In Ukraine the species is widespread in Transcarpathia, Prykarpattia, Transnistria, Opillia and Roztocze, Male Polissya, in the west of Podilla Upland, in Polissya, in the Forest-Steppe zone, occasionally in the northern part of the Steppe. According to Podorozhny (2010), *I. sibirica* was recorded on the Demerdzhi Yayla and on the border of the Dovhorukivska and Tyrke Yaylas in the Crimea.

Features of the structure of the *I. sibirica* inflorescence were interpreted differently. In particular, Chugaeva (2004) considers the upper group of flowers in *I. sibirica* as closed terminal florescence, and the lower – as paracladium. In our opinion, both complex monochasia – upper and lower, should be considered as axillary paracladia, as they are both covered with integumentary leaves (Skrypets & Odintsova, 2017). This is consistent with other data on the axillary location of paracladia in members of Iridaceae (Choob, 2000; Szôllôsi, 2010). In this case, the synflorescence in *I. sibirica* should be considered polythelic, without apical flower or inflorescence. According to Kuznetsova et al. (1992), in *I. sibirica* synflorescence is an open sawdust with 1–3 paracladia, constructed as small-flowered (1–3 flowers) complex fan-shaped monochasia, with different peduncle lengths and a significant degree of polyvariance in number, location and order of flowering.

The structure of the *I. sibirica* flower is well studied (Szőllősi et al., 2010; Odintsova & Skrypets, 2014), but we revealed a perigonal nectar on the inner surface of the perianth tube, which accumulates nectar and attracts pollinators such as *Apis mellifera* (Linnaeus, 1758) (honey bee) and *Bombus bombus* (Latreille, 1802) (bumble bee).

Fruit size corresponds to our previously published data for another population (Skrypets & Odintsova, 2015). In the literature it is stated that the number of seed germs varies between 46–83 pieces (Benseytova, 2009), which is significantly less than in the fruits we studied. It was also previously found that the seed germs and seeds in the fruit are located in two rows in each nest of the ovary, attached from the base to the top of the nest to the central column, do not hang (Skrypets & Odintsova, 2015). When studying the morphometric parameters of seeds, we find that they correspond to data from the territory of Ukraine (Sikura, 2014; Skrypets & Odintsova, 2015). However, they are slightly smaller than according to data from the territory of Russia (length – 4–6 mm, width – 4–5 mm) (Chugaeva, 2006).

According to Rodionenko (1961), in species of the genus *Iris* both of these methods of opening the capsule were noted, which starts from the top of the capsule and is carried out with two types of slits (dorsal and ventral) and slit, which is carried out only through dorsal slits in the middle capsules. However, for *I. sibirica*, these two types of capsule opening were discovered by us for the first time.

The phytophages from the genus *Ceutorrhynchus* that affected flower buds and fruits were also found in coenopopulations of *I. sibirica* (Iridaceae) in the floodplains of Bryansk region of Russia (Mu-Za-Chin & Shukla, 2016).

Note that according to Shvets (2005), species of the genus *Iris* are long-growing plants (vegetation period lasts about seven months), with stable spring-summer flowering, which lasts on average for about 20 days and fruiting, which lasts 50–80 days in the forest-steppe of Ukraine. For *I. sibirica*, we found a growing season of about nine months, which is slightly longer than for other species of the genus *Iris*.

According to Prokopchuk & Yarmolenko (2012) and Shvets (2005) in culture conditions, in *I. sibirica* the coefficient of seed productivity is about 75.5%, which is slightly higher than our data. The coefficient of seed productivity in our country is high and approaches the results of the study of this species in culture (75.5%) (Shvets, 2005). These data indicate high population stability.

In the literature it is noted that the average population density of *I. sibirica* is 19–260 shoots/m^2. And also it is observed that younger populations have more individuals compared to older populations. Therefore, our data coincide with data from Russia (Mu-Za-Chin & Shukla, 2016).

Conclusion

According to revised data, *I. sibirica* should be classified in the group of Euro-West Siberian, and not as a Euro-Siberian or even Eurasian species.

We found that the inflorescence of *I. sibirica* in the population from the botanical reserve of national importance "The Valley of the Irises" consists of 1–3 fan-shaped small-flowered monochasias. Stilodia of *I. sibirica* are flat, elongated, unevenly toothed, bilobed on the upper edge. We first discovered that on the inner surface of the flower tube there is a multilayer secretory tissue – perigonal nectar.

It was revealed that fruiting in *I. sibirica* lasts quite a long time: 2–3 months (60–80 days) from June to August. The coefficient of seed productivity of *I. sibirica* was high and quite stable, but despite the high potential and actual seed productivity in the coenopopulation there is a weak seed recovery, which is associated with high turfing and invasion of members of phytophagous genus *Ceutorhynchus*. Their activity dramatically reduces the maturation and dissemination of full-fledged mature seeds due to damage to flowers, capsules and seeds in them. However, the population of *I. sibirica* in the conditions of "The Valley of the Irises" is mature, normal, with a slight predominance of young individuals, which provides it with positive dynamics.

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