Journal of Siberian Federal University. Biology 2023 16(1): 41–53
~ ~ ~

EDN: LDJJAK

УДК 581.543:582.734.3(470.21)

Aspects of *Crataegus maximowiczii* C. K. Schneid Development on the Introduction above the Arctic Circle

Olesya E. Zotova* and Oxana A. Goncharova
Polar-Alpine Botanical Garden-Institute
of the Kola Science Center RAS
Apatity, Russian Federation

Received 10.08.2021, received in revised form 18.10.2022, accepted 08.02.2023

Abstract. This study aims to assess the developmental characteristics of *Crataegus maximowczii* C. K. Schneid on its introduction to the Kola Peninsula. Introduction of new plants aims to offer a range of highly ornamental trees and shrubs for municipal landscaping. Extending lists of highly viable and decorative plants that are suitable for landscaping has always been important. The paper describes the timing of phenological phases, morphometric parameters of inflorescences and fruits, as well as seed propagation under polar conditions. Phenological observations of plants were performed 2–3 times a week during the growing season. Morphometric characteristics of inflorescences were examined during the period of mass flowering of each specimen. The inflorescence density was determined as the ratio of the number of flowers in an inflorescence to its width, the fruit-to-flower ratio was determined as the percentage of full fruit number to the number of buds. A hundred seeds of each specimen were collected, and individual weight of each seed was determined using the analytical balance. Pre-sowing treatment included cold stratification or scarification followed by two-stage stratification. *Crataegus maximowiczii* has a short shoot growth period, short pre-floral period, annual flowering and fruiting. Flowering phases were first observed at the age of 8 years. Flowering and fruiting phases occurred annually; the abundance of flowering and fruiting was given 4–5 points on the five-point V. G. Kapper scale. The pre-floral period was of medium duration and lasted on average for 37 days. Fruit ripening occurred in September. The most stable parameter of the examined specimens was the number of flowers per inflorescence, while the number of fruits and, consequently, the fruit-to-flower ratio were more dependent on external conditions. Morphometric characteristics of inflorescences were species-specific. Average weight samples subjected to combined pre-sowing treatment had the highest germination rate.

* Corresponding author E-mail address: ol-sha@mail.ru
ORCID: 0000-0003-4986-606X (Zotova O.); 0000-0002-8881-8522 (Goncharova O.)

Keywords: phenological phases, flowering, fruit-to-flower ratio, seed weight, pre-sowing treatment, Subarctic.

Acknowledgements. The studies were carried out using the research facility "Collections of Living Plants of the Polar Alpine Botanical Garden and Institute", reg. No. 499394, within the framework of the research theme "Comprehensive analysis of methods for assessing decorativeness and their applicability to woody plants of the Far North (based on the PABSI collection of introduced woody plants of the KSC RAS)", state No. registration 1021071612833–7–1.6.11.

Citation: Zotova O. E., Goncharova O. A. Aspects of *Crataegus maximowiczii* C. K. Schneid development on the introduction above the Arctic Circle. J. Sib. Fed. Univ. Biol., 2023, 16(1), 41–53. EDN: LDJJAK.

Особенности развития *Crataegus maximowiczii* C. K. Schneid. при интродукции за Полярным кругом

О. Е. Зотова, О. А. Гончарова
Полярно-альпийский ботанический сад-институт им. Н. А. Аврорина
Российская Федерация, Апатиты

Аннотация. Данное исследование посвящено оценке развития *Crataegus maximowczii* при интродукции на Кольский Север. Одной из целей интродукции является разработка ассортимента высокодекоративных деревьев и кустарников для озеленения населенных пунктов. Пополнение списков растений, отличающихся высокой жизнеспособностью и декоративностью и подходящих для использования в озеленении, остается актуальным в настоящее время. В работе представлены сроки наступления фенологических фаз, морфометрические показатели соцветий, плодов, особенности семенного размножения при интродукции в условия Заполярья. Фенологические наблюдения за растениями проводили 2–3 раза в неделю в течение вегетационного сезона. Исследования морфометрических характеристик соцветий проведены в период массового цветения каждого образца. Плотность соцветий определяли как отношение числа цветков в соцветии к его ширине, процент плодоцветения определяли как отношение числа полноценных плодов к числу бутонов. С каждого экземпляра произведен отбор семян и определена индивидуальная масса каждого семени. Предпосевная подготовка проводилась методами холодной стратификации и скарификации с последующей двухэтапной стратификацией. У *Crataegus maximowiczii* короткий период роста побегов, непродолжительный префлоральный период, ежегодное цветение и плодоношение. Фазы цветения впервые отмечены в 8-летнем возрасте. Фазы цветения и плодоношения наблюдаются ежегодно, обилие цветения и плодоношения оценивается по шкале Капера в 4–5 баллов. Префлоральный период средней продолжительности длится в среднем 37 суток. Созревание плодов отмечается в сентябре. Фактор видовой специфичности влияет на морфометрические характеристики соцветий. У исследуемых экземпляров наиболее стабилен показатель количества цветков в соцветии, в то время как количество плодов и, следовательно, показатель плодоцветения в большей степени зависели от внешних условий. Наибольшей всхожестью обладают образцы со средними значениями массы, прошедшие комбинированную предпосевную подготовку.

Ключевые слова: фенологические фазы, цветение / плодоцветение, масса семян, предпосевная подготовка, Субарктика.

Благодарности. Исследования выполнены на базе уникальной научной установки «Коллекции живых растений Полярно-альпийского ботанического сада и института», обл. № 499394, в рамках темы «Комплексный анализ методик оценки декоративности и их применения к древесным растениям Крайнего Севера (на примере коллекции интродуцированных древесных растений ПАБСИ КНЦ РАН)», № гос. регистрации 1021071612833–7–1.6.11.

Цитирование: Зотова, О. Е. Особенности развития *Crataegus maximowiczii* C. K. Schneid. при интродукции за Полярным кругом / О. Е. Зотова, О. А. Гончарова // Журн. Сиб. федер. ун-та. Биология, 2023. 16(1). С. 41–53. EDN: LDJJAK.

Introduction

Plant introduction is one of the major activities of botanical gardens. Introduction of new plants aims to offer a range of highly ornamental trees and shrubs for municipal landscaping. Since the diversity of the native dendroflora of the Kola Peninsula is limited and the flowering period of woody plants is short, extending lists of highly viable and decorative plants that are suitable for landscaping remains topical. The paper is based on the research conducted at the Polar-Alpine Botanical Garden and Institute on *Crataegus maximowiczii* C. K. Schneid plants introduced to the Kola Peninsula.

Plants of *Crataegus* L. genus are distributed over a large territory in the northern hemisphere. They grow in the temperate and less often in the subtropical zone. Species of *Crataegus* genus are highly decorative during flowering and fruiting periods. For this reason they are widely used in landscaping. Flowering occurs at the age of 10–15 years. The flowering period follows leaf expansion in late May – early June. Complex cymose or umbellate inflorescences appear on short offshoots of the current year. The hawthorn (*Crataegus*) genus representatives are valuable as medicinal, fruit, and ornamental plants (Poletiko, 1954). On the Kola Peninsula, hawthorns are not found in natural plant communities; they occur as cultivated plants but do not require special care.

The results of introduction of the Rosaceae Juss. family plants in Russia are widely covered in scientific publications. O. V. Skrotskaya and S. A. Miftakhova (2011) presented the results of the Rosaceae family introduction in the Northeast of the European part of Russia. Introduction of the Rosaceae family in Yakutia is described in the papers by N. S. Danilova et al. (2006, 2011). N. A. Kolyada (2009, 2010) addressed the results of introduction of the Rosaceae family North American plants in the Russian Far East. Decorative qualities of the *Crataegus* genus plants were evaluated by S. V. Mukhametova et al. (2013). Some aspects of the *Crataegus* genus plants development and growth on the Kola Peninsula were addressed in the papers published by the staff members of the Polar Alpine Botanical

Garden and Institute (Goncharova et al., 2017; Zotova, Goncharova, 2019).

Recently, particular attention has been given to studying seed propagation of the *Crataegus* genus plants. Researchers have noted that hawthorn seeds remain dormant until favourable conditions occur; their thick endocarps prevent their germination (Vanstone et al., 1982; Nikolaeva, 1979; Vainagii, 1974). According to Nikolaeva et al. (1985), the dormancy of hawthorn seeds is combined: they have deep exogenous and intermediate physiological dormancy. In most cases, scarification or stratification is recommended for disturbing seed dormancy; combination of these methods is also possible (Morgenson, 2000; Bujarska-Borkowska, 2002, 2008).

The research aims to determine the timing of phenological phases, describe morphometric parameters of flowers and fruits and study seed propagation of *C. maximowiczii* on the introduction to polar regions.

Materials and methods

The study was conducted in 2015–2018 based on the collection of introduced tree species in the experimental site of the N. A. Avrorin Polar Alpine Botanical Garden and Institute of the Kola Scientific Center of the Russian Academy of Sciences (PABGI) in Apatity, Murmansk Oblast, Russian Federation. PABGI is one of the few botanical gardens within the Arctic Circle worldwide and the northernmost one in Russia (67°38’ N, 33°37’ E).

PABGI was founded in 1931 in the framework of the project launched by Professor N. A. Avrorin. The collection of PABGI woody plants is located at its main sites in Kirovsk and Apatity. The woody plants collection in Kirovsk was started with the foundation of PABGI and has been growing ever since. The tree nursery in Apatity was started in 1958. Both sites are located 120 km to the North of the Arctic Circle. The climate of the Murmansk Oblast is Arctic-temperate. The climate of the territory varies considerably. Although it may be severe due to its circumpolar situation, the close proximity to the warm Gulf Stream makes it more favourable. The territory of the PABGI experimental site is located on a piedmont plain, 3 km to the west of Apatity. The average monthly temperature in January-February does not drop below –13 °C; in July it varies from +10 to +14 °C. The first air frosts may be expected in August, the last frosts have been observed in late May and June. Thus, the duration of the frost-free season is about 50–70 days. The maximum precipitation occurs during the summer and autumn months, and minimum precipitation occurs in spring. The mean annual rainfall is 500–600 mm/year. A stable snow cover lasts from 180 to 200 days, the snow cover height being 60–80 cm. The transition of average daily air temperatures through the threshold of +5 °C is observed on 31st May. The growing season is 90–120 days (Semko, 1982).

The object of research, *C. maximowiczii*, is a prickly deciduous shrub or tree up to 7 m high. It is native to Eastern Siberia, Mongolia, northern China, northern Japan, and Korea. It appears at coastal forest strips, forest edges and dry mountain slopes, along roadsides and river banks. *C. maximowiczii* is a very cold-resistant plant, capable of withstanding temperatures up to –25 °C (Huxley et al., 1992). The inflorescences of *C. maximowiczii* are multi-flowered, up to 6 cm in diameter, with densely pubescent pedicels. The flowers are 1.5 cm in diameter, white, turn pink at the edge when they bloom, with an unpleasant smell. The sepals are narrow, triangular, whole-edged, pubescent, bent downwards in mature fruits. The flower has 20 stamina with dark pink anthers and 3–4 pistils. The fruits are red, pubescent, then glabrous, translucent. The flesh of the fruit is orange, powdery, edible, with

3–4 convex bones, smooth on the dorsal side, furrowed and wrinkled on the sides. The plant blooms at the end of May, fruits ripen in early August and remain on the trees until late autumn (Solovyova, Kotelova, 1986).

For the research, 3 specimens of hawthorn *C. maximowiczii* plants were selected. The age of the plants at the time of study was 17–20 years. The plants have grown from seeds of cultural origin obtained from the arboretum of the Institute of Forest and Forest Chemistry in Arkhangelsk, Russian Federation. In the study site, the introduced hawthorn plants are exhibited as a group under similar soil and ground conditions and exposed to specific climate of the Kola subarctic region.

Phenological observations of plants were performed 2–3 times a week during the growing season (Bulygin, 1976; Aleksandrova et al., 1975) in 2015–2018. We recorded the phenophase dates of vegetative buds burst, beginning and end of linear shoot growth, full lignification of annual shoots, leaf budding, completion of leaf growth and ripening, appearance of autumn leaf color, leaf fall, beginning and end of flowering, ripening of fruits. Duration of shoot growth, vegetation, pre-floral period and flowering was estimated (Aleksandrova, Golovkin, 1978). Abundance of flowering and fruiting was evaluated by the V. G. Kapper scale (1930).

Morphometric characteristics of inflorescences were examined in 2018 during mass flowering of each specimen. Ten inflorescences per plant were randomly selected from the middle part of the crown. The inflorescence and flower sizes were determined by the largest diameter using a ruler with a measurement accuracy of 0.1 cm. The inflorescence density was determined as the ratio of the number of flowers in an inflorescence to its width (Mukhametova et al., 2013). The fruit-to-flower ratio was determined as the percentage of full fruit number to the number of buds (Vainagii, 1974). Fruits (100–150 pcs) were harvested in different parts of the crown during their full ripening in September 2017. The fruit size was measured using a caliper to the nearest 0.1 mm.

Seeds were harvested in August-September for three years (2015–2017). A hundred seeds were collected from each specimen, and the individual weight of each seed was determined using the analytical balance VLR-200 to the nearest 0.0001 g. Seeds were grouped into classes according to their weight using the variation statistics methods (Dospekhov, 1985).

Pre-sowing treatment included (I) cold stratification or (II) scarification followed by two-stage stratification.

The 2015 harvest seeds were subjected to cold stratification, which stimulates seed germination from the state of the deepest dormancy (Nikolaeva, 1979). Seeds were preliminarily washed in running water for three days, then kept in plastic containers in a refrigerator at a temperature of 4–6 °C from 1st March to 12th May, 2016. The stratification medium included fibric high-moor peat with addition of sapric peat, pH 5.59–6.50, nitrogen (NH_4 + NO_3) – no less than 200 mg/l, phosphorus (P_2O_5) – no less than 200 mg/l, potassium (K_2O) – no less than 250 mg/l. Control samples of seeds in the same substrate were kept in a dark room at a temperature of 22–25 °C, for the same period from 1st March to 12th May, 2016.

The 2016 harvest seeds underwent combined pre-sowing treatment (scarification followed by two-stage stratification). This technique stimulates seed germination from the state of combined dormancy (Crocker, 1948). Seeds were soaked in a concentrated solution of sulfuric acid (H_2SO_4) for 60 minutes and washed under running water for three minutes, then subjected to two-stage stratification. High-moor peat was also used as a stratification medium. At the first stage, seeds were kept in a dark room at 22–25 °C from

3rd January to 1st March, 2017. At the second stage of stratification, seeds were kept in a refrigerator at 4–6 °C from 1st March to 18th June, 2017.

Stratified seeds of the 2015 harvest were sowed on 12th May, 2016. Scarified and stratified seeds of the 2016 harvest were sowed on 18th June, 2017. Stratified, scarified and control seeds were germinated in soil in sowing boxes in an open greenhouse. Soil composition for germination included peat, sand, limestone flour, expanded clay drainage, pH – 5.9–6.5, nitrogen (NH_4 + NO_3) – 325 mg/kg, phosphorus (P_2O_5) – 370 mg/kg, potassium (K_2O) – 500 mg/kg.

Statistical parameters were calculated using the Microsoft Excel application following standard methods (Ivanter, Korosov, 2003; Korosov, Gorbach, 2010).

Results and discussion

In the subarctic climate of the Kola Peninsula, the examined *C. maximowiczii* plants retained their habitus, had a well-formed trunk and branches, and showed yearly lignification of annual shoots, average shoot-forming ability and annual growth in height; also, self-seeding was observed.

Table 1 shows phenological observations of the plant vegetative organs in 2015–2018. They are compared with long-term average annual data (2001–2015) published earlier (Goncharova et al., 2017).

During 2015–2018, the vegetation onset of *C. maximowiczii* was observed during late April to late May. Appearance of autumn leaf color was observed from the end of August to the middle of September (according to the long-term observations, the average annual date is 3rd September). In 2016, the growing season was longer due to the earlier start. In general, our observations allow to classify *C. maximowiczii* as a plant with an early onset and short growing season according to Aleksandrova-Golovkin scale (1978).

Plants enter the phase of linear shoot growth from the middle of May to the middle of June. Before the end of the growing season, shoot linear growth and lignification of the observed specimen normally come to an end. By linear shoot growth duration, *C. maximowiczii* can be classified as a plant with a short period of shoot growth.

The timing of flowering and fruiting phenophases is shown in Table 2. The flowering phase was first observed at the age of 8 years. The phases of flowering and fruiting were observed every year; the abundance of flowering and fruiting was given 4–5 points on the five-point V. G. Kapper scale. Pre-floral period was of medium duration and lasted on average for 37 days. Fruit ripening was observed in September.

The timing of the phenological phases varies from year to year, which is explained by

Table 1. The timing of the onset of vegetative phenological phases in *C. maximowiczii* in 2015–2018

Years	Phenological phases								Dg, day	VP, day
	Vb 2	Gs 1	Gs 2	Lig 2	L 1	L 3	L 4	L 5		
2015	8.V	29.V	6.VII	31.VII	25.V	22.VI	1.IX	28.IX	38	116
2016	30.IV	18.V	20.VI	1.VIII	5.V	17.VI	6.IX	25.IX	33	129
2017	25.V	14.VI	2.VIII	21.VIII	8.VI	10.VII	15.IX	20.VII	49	113
2018	10.V	21.V	5.VII	18.VIII	19.V	22.VI	28.VIII	27.IX	45	110
2001–2015*	18.V	30.V	20.VII	6.VIII	25.V	23.VI	3.IX	1.X	51	108

Vb 2 – vegetative buds burst, Gs 1 / Gs 2 – beginning and end of linear shoot growth, Lig 2 – full lignification of annual shoots, L 1 – leaf budding, L 3 – completion of leaf growth and ripening, L 4 – appearance of autumn leaf color, L 5 – leaf fall; Dg – duration of shoot growth, VP – growing season. * Data from (Goncharova et al., 2017).

Table 2. The timing of the onset of the phenological phases of flowering and fruiting in *C. maximowiczii* in 2015–2018

Years	Phenological phases			PFP, day / DF, day
	Fl4	Fl5	Fr3	
2015	26.VI	10.VII	17.IX	49/14
2016	14.VI	24.VI	23.VIII	45/10
2017	15.VII	20.VII	22.IX	51/5
2018	20.VI	30.VI	8.IX	41/10
2001–2015*	24.VI	1.VII	1.IX	37/7

Fl4 / Fl5 – beginning and end of flowering, Fr 3 – ripening of fruits, PFP – pre-floral period, DF – duration of flowering. * Data from (Goncharova et al., 2017).

the weather conditions of the growing season. The closest to the average long-term data are the phenophases of 2018 (Table 2).

Seed weight distribution was obtained using the methods of variation statistics. Individual seed weight distribution curves of the 2015–2017 harvest are shown in Fig. 1. Approximation of variants to the symmetric normal distribution curve was noted in 2015. In other years, asymmetric distribution of individual seed weight was common. A shift towards the smallest weights was observed, which could be due to the least favourable factors of the growing season.

The individual seed weight distribution curves of individual specimens in 2017 are shown in Fig. 2. *C. maximowiczii* plants under examination differed in seed weight values. The smallest values of seed weight were noted for specimen 1, the highest ones for specimens 2 and 3. Hence, distribution of variants of specimen 1 shifted from the average toward the smallest value. Since all specimens were subjected to an identical set of environmental factors, the effect of endogenous factors on the studied parameter seems unclear.

According to the observations, no seeds germinated during the first year, which corresponds

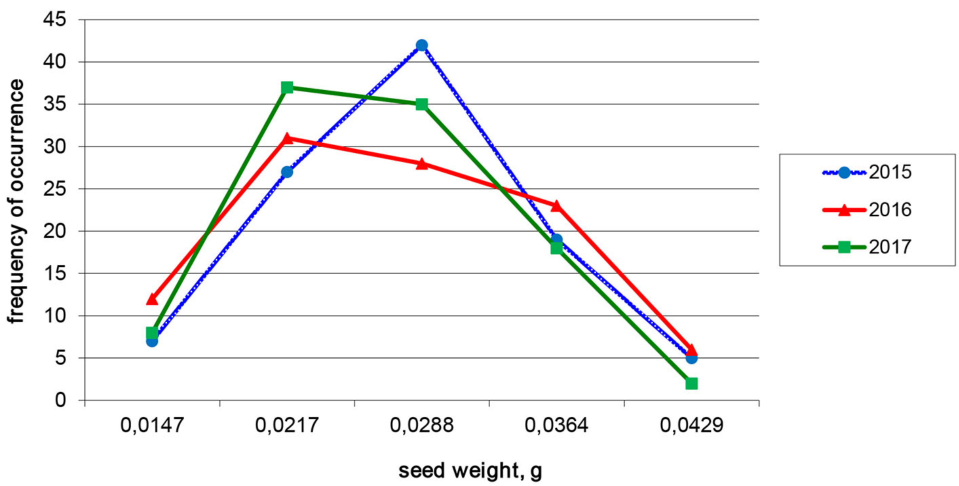

Fig. 1. Distribution of seed weight of *C. maximowiczii* in 2015, 2016, and 2017, total of 100 seeds collected from each of the three examined specimens

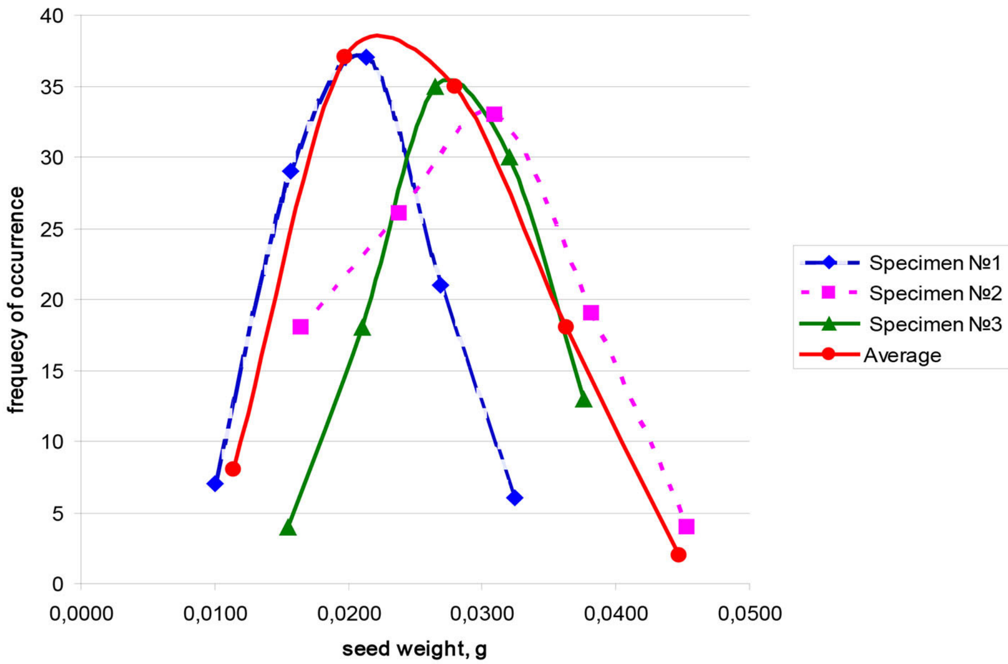

Fig. 2. Distribution of seed weight of individual *C. maximowiczii* plants in 2017

to the referenced data that seedlings appear on the second or the third year (Nikolaeva, 1979; Tyszkiewicz, 1949). The absence of germination under favourable conditions can be accounted for by organic dormancy of the seeds themselves.

The observations continued during the growing seasons of 2017–2018. Seedlings from all samples subjected to a variety of pre-sowing treatments were obtained within the period from June 14 to 30, 2017–2018. Field germination of the studied species was estimated as a percentage of the number of seedlings out of the number of seeds sown. Field germination was estimated for each weight class.

The highest germination of *C. maximowiczii* seeds amounted to 35 % and was observed for seeds with an average weight of 0.0303 g subjected to a combined pre-sowing treatment. For stratified samples with an average weight of 0.0336 g, the germination equaled 31 %. Samples with the highest seed weights (0.0427 g) did not germinate; the germination rate of low-weight seeds (0.0178 and 0.0241 g) was negligible, regardless of pre-sowing treatment. Germination of samples that did not undergo pre-sowing treatment was observed only in seeds of the fourth class (0.0336 g) and amounted to 20 % (Fig. 3).

An analysis of field germination dependence on individual seed weight of the *C. maximowiczii* representatives revealed that the germination rate depended on pre-sowing treatment and seed weight. Samples with average weight values that underwent combined pre-sowing treatment had the highest germination ability.

A similar positive effect of the two-stage pre-sowing treatment (a combination of acid scarification and cold stratification) on germination of some *Crataegus* species was noted by Morgenson G. (2000), Bujarska-Borkowska B. (2002, 2008). A positive effect of warm and cold stratification was also noted (Nyholm, 1975).

At the next stage, the degree of flowering and fruiting of *C. maximowiczii* plants was evaluated

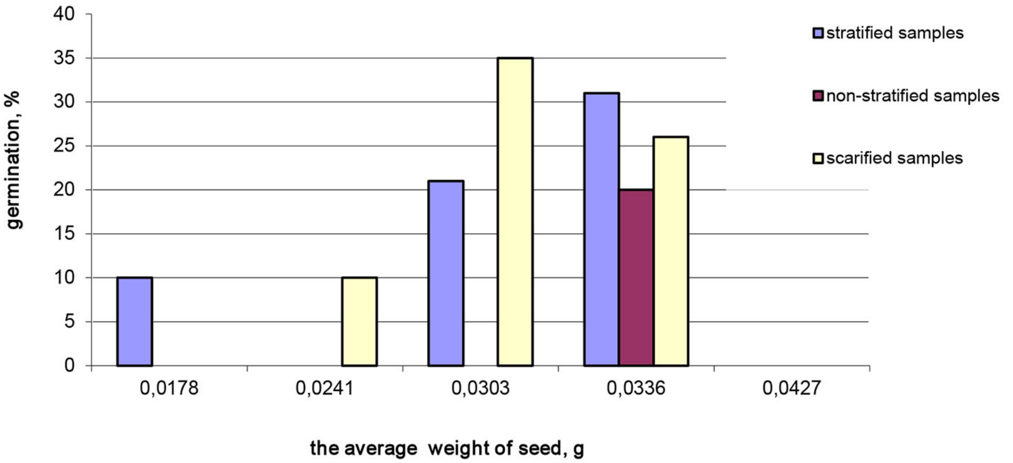

Fig. 3. Germination of *C. maximowiczii* seeds of different weight

Table 3. Morphometric parameters of *C. maximowiczii* flowers and inflorescences on the introduction in 2018

Instance	Inflorescence diameter, cm	Flower diameter, cm	Number of flowers in the inflorescence, pcs.	Inflorescence density, pcs./cm
1	6.63±0.30	1.62±0.05	28.00±1.43	4.23±0.21
2	4.96±0.27	1.37±0.05	21.45±1.34	4.50±0.42
3	6.37±0.30	0.52±0.05	33.40±2.23	5.37±0.47
Mean	5.95±0.21	1.50±0.03	27.42±1.29	4.69±0.23

(Table 3). These important indicators determine seed propagation under new conditions.

The examined *C. maximowiczii* specimens differed in morphometric parameters of flowers and inflorescences. The smallest inflorescence width was observed in specimen 2, the maximum width in specimen 1. The average inflorescence width of the studied plants was 5.95 ± 0.21 cm. The minimum diameter of flowers was observed in specimen 3 (0.52 cm), the maximum width in specimen 1 (1.62 cm). The average flower width was 1.5 ± 0.03 cm.

Specimens 3 and 1 had the largest number of flowers. The density of inflorescences was the highest (5.37 pcs/cm) in specimen 3, specimen 1 had lower density inflorescences (4.23 pcs/cm). Specimen 2 had the smallest number of flowers in an inflorescence and the smallest diameter of inflorescences. The average density of inflorescences was 4.69 ± 0.23 pcs/cm.

A correlation analysis showed a positive relationship between the average number of flowers and inflorescence density ($r = 0.65$ at $\alpha = 0.001$) and between the sizes of inflorescences and flowers ($r = 0.64$ at $\alpha = 0.001$). It means that, specimens with denser inflorescences are characterized by larger numbers of flowers in the inflorescence. Samples with small flower size form small inflorescences and vice versa. No reliable correlation between the inflorescence density and flower size, between the width of inflorescences and their density and between the size of flowers and their number was revealed.

We have previously studied morphometric parameters that determine the decorative qualities of flowers and inflorescences, i.e. the number of flowers in the inflorescence, the diameter of flowers, the diameter and density of inflorescences, in *C. maximoviczii*, *C. dahurica*, *C. sanguinea*, *C. laevigata*, *C. flabellate* (Zotova, Goncharova, 2019). It was shown that *Crataegus* species are most decorative during flowering. *C. maximowiczii* and *C. dahurica* have the largest flowers and inflorescences. The dependence of morphometric characteristics of inflorescences on species affiliation was studied using the single-factor analysis of variance. The factor of species affiliation affects the morphometric characteristics of inflorescences. A single-factor analysis of variance showed that the species affiliation contributed 63 %, 47 %, 31 % and 23 % to the variance of the number of flowers in inflorescence, inflorescence width, flower diameter and inflorescence density, respectively. Under the subarctic conditions of the Kola Peninsula, the number of flowers in inflorescences largely depends on species affiliation, whereas other studied parameters are less affected by it. Based on these observations, *C. maximowiczii* is recommended for use in landscaping of northern cities as a species with highly decorative large inflorescences.

In the environment of the Kola Peninsula, *C. maximowiczii* plants bear fruits of regular shape without significant damage. The fruit-to-flower ratio in *C. maximowiczii* plants on introduction over a three-year period (2016–2018) showed stability, the deviation from the average value in different years was ±6.7 % (Fig. 4). The most stable parameter of the studied specimens was the number of flowers in an inflorescence, while the number of fruits and, consequently, the fruit-to-flower ratio were more dependent on external conditions. Morphometric parameters of the *C. maximowiczii* fruits on the introduction are shown in Table 4.

Notwithstanding homogeneous soil and climate conditions, the specimens showed varying fruit-to-flower ratios and fruit diameters (Table 4). The average fruit diameter of specimens 2 and 3 (9.7 ± 0.2 and 9.9 ± 0.2 mm, respectively) was close to the average values of 10.0 mm (Solovyova, Kotelova, 1986). The variation factor for the fruit size was 14.71 %, which corresponds with low variability level of this parameter by the S. A. Mamaev scale (1972). Hence, under the conditions of introduction to the Kola subarctic region, *C. maximowiczii* plants

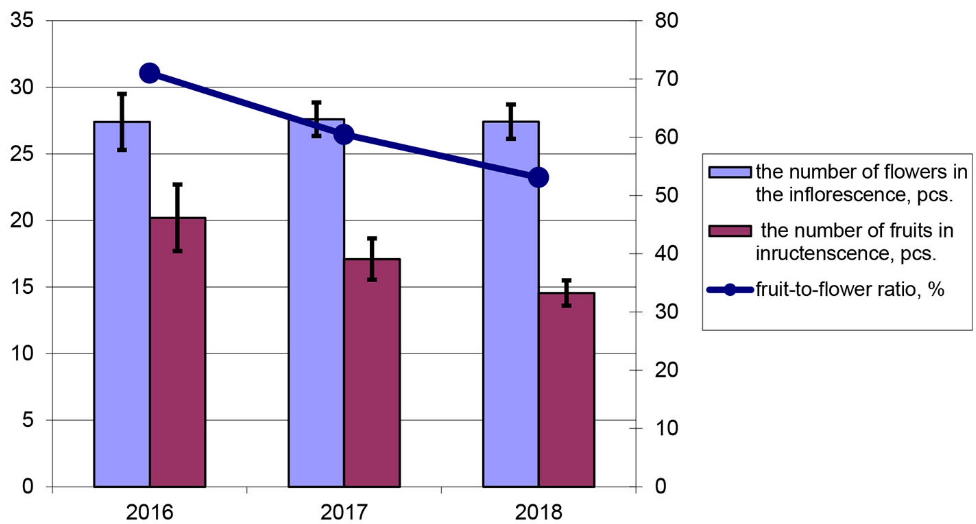

Fig. 4. Fruit-to-flower ratio of *C. maximowiczii* plants in 2016-2018

Table 4. Morphometric parameters of *C. maximowiczii* fruits and the fruit-to-flower ratio on the introduction in 2018

Instance	The number of fruits in infructescence, pcs.	Diameter of fruits, mm	Fruit-to-flower ratio, %
1	19.80±1.41	12.5±0.2	70.7
2	12.45±1.37	9.7±0.2	58.1
3	11.60±0.83	9.9±0.2	34.7
Mean	14.55±0.95	10.7±0.2	53.1

can be classified as small-fruited; the size of fruits is determined not only by species affiliation but varies phenotypically within the species.

Conclusion

Phenological development of *C. maximowiczii* is determined by environmental conditions of the Kola Peninsula, these plants complete a full development cycle, are winter-resistant and viable. *C. maximowiczii* has a short growing season with an early start. The average duration of the growing season is 108 days. Plants enter the generative stage of ontogenesis at the age of 8 years. The phases of flowering and fruiting are observed annually. A short pre-floral period provides enough time for seed ripening. To stimulate seed germination, a combined pre-sowing preparation is recommended: thermal and cold stratification, acid scarification and cold stratification.

References

Aleksandrova M. S., Bulygin N. E., Voroshilov V. N. (1975) *Guidelines on phenological observation in the botanical gardens of the USSR*. Moscow, Main Botanical Garden USSR, 28 p. (in Russian)

Aleksandrova N. M., Golovkin B. N. (1978) *Introduction of trees and shrubs to the Far North*. Leningrad, Nauka, 116 p. (in Russian)

Bujarska-Borkowska B. (2002) Breaking of seed dormancy, germination and seedling emergence of the common hawthorn (*Crataegus monogyna* Jacq.). *Dendrobiology,* 47: 61–70

Bujarska-Borkowska B. (2008) Seed dormancy breaking in *Crataegus pedicellata*. *Dendrobiology*, 60: 51–56

Bulygin N. E. (1976) *Dendrology. Phenological observation of deciduous woody plants*. Leningrad, Forest Technical Academy, 70 p. (in Russian)

Crocker W. (1948) *Growth of plants*. New York, Reinhold Publishing Corporation

Danilova N. S., Rogozhina T. Yu., Romanova A. Yu., Borisova S. Z., Ivanova N. S. (2011) Introduction stability of plants is a basic of working out of ornamental plants assortment for towns of the Central Yakutia. *Bulletin of Irkutsk State University. Series "Biology. Ecology"* [Izvestiia Irkutskogo gosudarstvennogo universiteta. Seriia «Biologiia. Ekologiia»], 4(2): 17–22 (in Russian)

Danilova N. S., Romanova A. Yu., Rogozhina T. Yu. (2006) Methods of selection of introduced species for Central Yakutia. *Bulletin of Yakutsk State University* [Vestnik Iakutskogo gosudarstvennogo universiteta], 3(4): 14–21 (in Russian)

Dospekhov B. A. (1985) *Field experiment methodology (with the basics of statistical research results processing)*. Moscow, Agropromizdat, 351 p. (in Russian)

Goncharova O. A., Poloskova E. Yu., Zotova O. E., Lipponen I. N. (2017) Introduction of *Crataegus* L. samples in the Kola North. *Samara Journal of Science* [Samarskii nauchnyi vestnik], 6(2): 31–35 (in Russian)

Huxley A. J., Griffiths M., Levy M. (1992) *The new RHS dictionary of gardening*. London, MacMillan Press

Ivanter E. V., Korosov A. V. (2003) *Introduction to quantitative biology: textbook*. Petrozavodsk, Petrozavodsk Statet University, 304 p. (in Russian)

Kapper V. G. (1930) On the organization of annual systematic observations of tree species fruiting. *Papers on forest experimental work. Issue 8*. Leningrad, State Institute of Forestry, p. 103–139 (in Russian)

Kolyada N. A. (2009) Results of introduction of North-American species of family Rosaceae in the conditions of the south of Primorye Territory. *Bulletin of the Botanical Garden-Institute FEB RAS* [Biulleten' Botanicheskogo sada-instituta DVO RAN], 3: 87–90 (in Russian)

Kolyada N. A. (2010) Botanical and geographical analysis of the collection of North American species of Rosaceae Juss. family introduced at the arboretum of mountain-taiga station of the Far Eastern Branch of the Russian Academy of Sciences. *Proceedings of Voronezh State University. Series: Geography. Geoecology* [Vestnik Voronezhskogo gosudarstvennogo universiteta. Seriia: Geografiia. Geoekologiia], 2: 57–59 (in Russian)

Korosov A. V., Gorbach V. V. (2010) *Computer processing of biological data: a handbook of methodology*. Petrozavodsk, Petrozavodsk State University, 84 p. (in Russian)

Mamaev S. A. (1972) *Intraspecific variation of woody plants (in Pinaceae family of the Urals)*. Moscow, Nauka, 284 p. (in Russian)

Morgenson G. (2000) Effects of cold stratification, warm-cold stratification, and acid scarification on seed germination of 3 *Crataegus* species. *Tree Planters' Notes*, 49(3): 72–74

Mukhametova S. V., Grigoryeva K. Yu., Faizullina G. M. (2013) Ornamental qualities of hawthorn inflorescences and flowers. *Subtropical and Ornamental Horticulture* [Subtropicheskoe i dekorativnoe sadovodstvo], 49: 122–127 (in Russian)

Nikolaeva M. G. (1979) *Accelerated germination of dormant seeds of woody plants*. Leningrad, Nauka, 80 p. (in Russian)

Nikolaeva M. G., Razumova M. V., Gladkova V. N. (1985) *Handbook on germination of dormant seeds*. Leningrad, Nauka, Leningrad Branch, 348 p. (in Russian)

Nyholm J. (1975) Germination of tree seeds. Dormancy. *Acta Horticulture*, 54: 21–24

Poletiko O. M. (1954) Hawthorn-*Crataegus* L. *Trees and shrubs of the USSR. Vol. 3*. Moscow, Leningrad, USSR Academy of Sciences, p. 514–577 (in Russian)

Semko A. P. (1982) *Hydrothermal soil regime of the forest zone of the Kola Peninsula*. Apatity, Kola Branch of USSR Academy of Science, 142 p. (in Russian)

Skrotskaya O. V., Miftakhova S. A. (2011) Some kinds of the family Rosaceae Juss.: introduction and prospects of cultivation in the north. *Bulletin of the Irkutsk State Agricultural Academy* [Vestnik IrGSKhA], 44: 122–130 (in Russian)

Solovyova N. M., Kotelova N. V. (1986) *The Hawthorn*. Moscow, Agropromizdat, 72 p. (in Russian)

Tyszkiewicz S. (1949) *The forest seeds*. Warsaw, Forest Research Institute

Vainagii I. V. (1974) On the techniques of seed productivity research. *Botanical Journal* [Botanicheskii zhurnal], 59(6): 826–831 (in Russian)

Vanstone D. E., Ronald W. G., Marshall H. H. (1982) *Nursery propagation of woody and herbaceous perennials for the Prairie Provinces*. Ottawa, Agriculture Canada

Zotova O. E., Goncharova O. A. (2019) Morphometric characteristics of inflorescences and phenology of introduced plants of the genus *Crataegus* L. in the Kola subarctic conditions. *Samara Journal of Science* [Samarskii nauchnyi vestnik], 8(3): 42–46 (in Russian)