

Flowering features of rare fruit plants of the Rosaceae Juss. family

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Abstract. One of the ways to solve the problem of food security is to increase the proportion of non-traditional crops' fruits in the diet with valuable consumer characteristics and a wide range of application in fruit growing, selection, and greening. The seasonal development rhythm - especially the flowering phase - is important in the study of rare fruit plants introduced into culture as it determines the plants' resistance to adverse environmental factors and the ability to produce full-fledged fruits and seeds. The purpose of this research was to study the flowering characteristics of non-traditional fruit crops of the Rosaceae Juss. family to determine the prospects of their use in selection and greening. From 2012 to 2021, 16 species were studied in the arboretum of the Russian Research Institute of Fruit Crop Breeding (VNIISPK, Orel, Russian Federation). The flowering calendar compiled on the basis of the conducted phenological observations shows various dates of the objects' flowering onset, which makes it possible to use them as ornamental plants when creating parks and gardens of continuous flowering. *Chaenomeles Maulei*, *Malus niedzwetzkyana*, *Crataegus submollis* and *Padus virginiana* have the most ornamental blossoming. Of these, *Chaenomeles Maulei* has the longest flowering period (more than 20 days). A consistently high flowering degree (4.5-5.0 points) was observed in twelve objects, which determines the prospects of their application in the selection process as sources of certain economically valuable traits: early flowering (*Malus prunifolia* and *Sorbus aria*), long-term flowering (*Chaenomeles Maulei*, *Malus prunifolia* and *Rosa canina*), a high ornamental flowering degree (*Chaenomeles Maulei*, *Malus niedzwetzkyana*, *Crataegus submollis* and *Padus virginiana*).

1 Introduction

In the context of global urbanization, the issue of agricultural development as a guarantee of food security, including providing people with a healthy diet, is acute [1, 2]. Full and regular body supply with all the necessary substances is one of the most important and urgent tasks of modern society in solving the problem of maintaining health and increasing human life expectancy. One of the ways to solve this problem is to increase the proportion of non-traditional crops' fruits in the diet [3, 4]. In this regard, there is a growing interest in rare fruit and berry plants with valuable consumer characteristics, a wide usage range in fruit growing, selection, greening, and meeting modern requirements for resistance to abiotic and biotic

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environmental factors [5-8]. Rare fruit and berry plants have developed a high resistance to adverse environmental conditions for thousands of years, which they store in their genoplasm. Accordingly, as opposed to the collection of wild fruits, their industrial-basis cultivation is becoming more and more relevant [5, 6, 9].

The study of plant phenology and the identification of seasonal development patterns of each individual phase and the whole plant is of great scientific and practical interest for biology, agriculture, and the greening practice of populated areas. The study of the plants' seasonal development dynamics is essential when selecting an assortment for greening, to assess the aesthetic and sanitary-hygienic properties of plants, when developing and carrying out measures to increase the biological stability of green spaces, their protection from pests and diseases [10, 11]. The materials of phenological observations are used in the calendars' compilation of plant flowering, ripening, and harvesting fruits and seeds, in determining the optimal timing of sowing and planting [11-13]. The seasonal development rhythm is important in the study of rare fruit plants introduced into culture as it determines not only the plants' resistance to adverse environmental factors, but also the ability to bloom and produce full-fledged fruits and seeds. Fruit set directly depends on the beginning, sequence, flow, duration, and abundance of flowering. Accordingly, it is flowering that is one of the most important factors in obtaining good yields of fruit crops [13, 14]. Many non-traditional fruit crops belong to the Rosaceae Juss. family. The purpose of this research was to study the flowering characteristics of non-traditional fruit crops of the Rosaceae Juss. family to determine the prospects of their use in selection and greening.

2 Materials and Methods

The research was conducted from 2012 to 2021 in the conditions of the arboretum of the Russian Research Institute of Fruit Crop Breeding (VNIISPK, Russia) located in the European part of Russia 368 km southwest of Moscow (53°00'N, 36°00'E), one and a half kilometers from the city of Orel in close proximity to the busy Orel-Bolkhov highway, from which it is separated by a single-row planting of *Tilia cordata* [15]. To date, the bioresource collection has more than 340 species, forms, and varieties of plants planted according to the geographical principle. Fruit and berry plants make up only 9.5% of the total number of taxa in the arboretum's genetic collection and include 6 families. The Rosaceae family is the most numerous in terms of rare fruit plants in the arboretum gene pool [8]. 16 species of various ecological and geographical origin belonging to 8 genera were selected as research objects (table 1). The study of the phenological phases' passage rhythms of plants was carried out according to the methodology of the Main Botanical Garden of RAS named after N.V. Tsitsin [16]; determination of winter hardiness – visually in the field at the end of budding on the 7-point scale by P. I. Lapin and S. V. Sidneva [17], with 1 being the highest winter hardiness score; the plants' flowering degree – on the 6-point scale by A. G. Golovach [18], with 5 being the highest score; the ornamentality degree in accordance with the method of O. Yu. Emelyanova [19]. Calculations and statistical processing of research results were performed using the Microsoft Excel 2016 software package.

3 Results and Discussion

In the VNIISPK arboretum, observations of the main phenological phases of various genetic collection groups are an integral part of scientific research that allows predicting the plants' behavior when introduced into culture. The timing and duration of flowering are especially important to study the rhythms of rare fruit species. Flowering is one of the most important phenological phases; its passage (timing, duration, flowering degree) largely determines the

final crop yield [8, 13, 14]. In the process of achieving the goal of these studies, it was revealed that weather conditions affected the start timing of species' flowering.

Table 1. Some ecological and biological features of research objects.

No.	Type	Year of planting	Winter hardiness	Degree of flowering	The degree of ornamental flowering
Far East					
1.	<i>Chaenomeles Maulei</i> (Mast.)Schneid.	2015	1,0	4,9	15
2.	<i>Malus niedzwetzkyana</i> Dieck.	1976	1,0	5,0	15
3.	<i>Malus prunifolia</i> (Willd.) Borkh.	2014	1,0	4,7	12
4.	<i>Malus x purpurea</i>	2014	1,1	4,4	12
5.	<i>Padus Maackii</i> (Rupr.)Kom.et Alisova	1977	1,0	5,0	12
6.	<i>Sorbus alnifolia</i> (Siebold et Zucc.) K. Koch	1969	1,0	4,6	12
Europe					
7.	<i>Amelanchier ovalis</i> Medik.	1978	1,0	5,0	12
8.	<i>Mespilus germanica</i> L.	2013	1,1	3,4	6
9.	<i>Padus racemosa</i> (Lam.)Gilib.	1979	1,0	5,0	12
10.	<i>Rosa canina</i> L.	2014	1,0	4,5	12
11.	<i>Sorbus aria</i> (L.)Crantz	1969	2,1	4,1	9
12.	<i>Sorbus aucuparia</i> L.	1969	1,0	4,9	12
North America					
13.	<i>Crataegus submollis</i> Sarg.	1977	1,0	5,0	15
14.	<i>Padus virginiana</i> (L.)Mill.	1976	1,0	5,0	15
15.	<i>Sorbus americana</i> Marsch.	1969	1,8	4,6	12
Siberia					
16.	<i>Sorbus sibirica</i> Hedl.	1974	2,6	2,1	6
Variation coefficient V, %			39,65	17,18	23,59

In years with warm weather, plants' flowering was observed in earlier timing; just the opposite happened in cold weather. At the same time, high average daily temperatures shorten the flowering duration. The abundance of flowering depends on this crop's adaptation degree in the growing region and on the conditions of the previous winter period. The flowering calendar was compiled based on the conducted phenological observations (table 2, 3).

Table 2. Notations of phenological phases.

	Swelling and opening of generative buds
	Budding
	Flowering

The earliest flowering onset was observed in *Malus prunifolia* and *Sorbus aria* (mid-1st decade of May). Then *Chaenomeles Maulei*, *Malus x rigrigea*, *Padus Maackii* and *Padus racemosa* joined the flowering (beginning of the 2nd decade of May). The latest flowering – *Mespilus germanica* and *Rosa canina* (mid-3rd decade of May). The longest flowering was observed in *Chaenomeles Maulei*, *Malus prunifolia* and *Rosa canina* (more than 20 days).

Table 3. Flowering terms of the study objects (on average over the years of study).

No.	Type	Decades of months						
		April		May			June	
		III	I	II	III	I	II	
Far East								
1.	<i>Chaenomeles Maulei</i>							
2.	<i>Malus niedzwetzkyana</i>							
3.	<i>Malus prunifolia</i>							
4.	<i>Malus x purpurea</i>							
5.	<i>Padus Maackii</i>							
6.	<i>Sorbus alnifolia</i>							
Europe								
7.	<i>Amelanchier ovalis</i>							
8.	<i>Mespilus germanica</i>							
9.	<i>Padus racemosa</i>							
10.	<i>Rosa canina</i>							
11.	<i>Sorbus aria</i>							
12.	<i>Sorbus aucuparia</i>							
North America								
13.	<i>Crataegus submollis</i>							
14.	<i>Padus virginiana</i>							
15.	<i>Sorbus americana</i>							
Siberia								
16.	<i>Sorbus aucuparia subsp. sibirica</i>							

The presence of full flowering makes it possible to predict the potential yield of fruits and the possibility of using species in selection as sources of certain economically valuable traits. Annual flowering is observed in all the study objects. However, the flowering degree varies among them is different; in individual species, it depends on their ability to withstand a complex of environmental influences during the winter and early spring periods. The winter hardiness of the arboretum plants was determined visually in the field upon the budding completion - when the damage is most noticeable. Different wintering conditions were observed in the Orel region during the research years: from mild (with stable negative temperatures and constant snow cover) to quite severe (with sharp temperature fluctuations and almost no snow). Studies have shown that good winter hardiness and a consistently high

degree of flowering (4.5-5.0 points) was observed in twelve objects (Table 1). Counting from the full flowering characteristic of this species, blossoming amounted to 75% to 100% of flowers. In winter hardiness, the study objects had a high degree of trait variability (coefficient of variation 39.65%).

In some years, *Mespilus germanica* had damage to annual shoots of up to 50% of the length. Up to 100% of the annual shoots' length and partially older shoots can be damaged in *Sorbus aria* and *Sorbus sibirica*. Shoots' freezing leads to a decrease in the flowering degree in the corresponding years. In years with early warm spring and recurrent frosts, *Sorbus aria* young leaves and buds may freeze due to early budding and the beginning of shoot growth. But the plant quickly recovers in the same year. However, the obtained damage also negatively affects the flowering degree. According to the fruiting degree, the set of objects was fairly homogeneous with an average degree of trait variability (coefficient of variation 17.18%).

Along with valuable nutritional and medicinal properties, non-traditional fruit introducers also possess original ornamental qualities [20]. All the studied objects have ornamental flowering. The degree of ornamental flowering was determined by the scale of O.Yu. Emelyanova [19] multiplying the score by the weighting coefficient "3" according to the method. When assessing the ornamental flowering qualities, their shape and color were considered together with the contrast with the general crown color background and the abundance of flowering, that is, the percentage of the crown area occupied by flowers or inflorescences. In accordance with this attribute, the totality of the research objects has significant variability (coefficient of variation 23.59%). A low degree of ornamental flowering was shown by *Mespilus germanica* (6 points), *Sorbus aria* (9 points) and *Sorbus sibirica* (6 points). *Mespilus germanica* has elegant white flowers up to 3.5 cm in diameter, which moderately contrast with the green foliage background and occupy less than 15% of the crown area, which does not allow to highly appreciate this species' flowering ornamentality in research conditions (Fig. 1, A). *Sorbus aria* inflorescences occupy up to 40% of the crown area, but have little contrast with the silvery foliage. *Sorbus sibirica*, as mentioned above, often freezes in winter and blooms poorly. Four research objects had the highest degree of flowering ornamentality (15 points): *Chaenomeles Maulei*, *Malus niedzwetzkyana*, *Crataegus submollis* and *Padus virginiana* (Table 1). *Chaenomeles Maulei* has flowers up to 4 cm in diameter of saturated orange-carmine shades collected in inflorescences of 2-6 flowers. They contrast well with the young light green shiny leaves (fig. 1, B). The buds' flowering does not occur simultaneously, which ensures a fairly long flowering period (Table 3). The flowers of *Malus niedzwetzkyana* are dark purple in the buds, intensely pink or purple when blooming, on thin white tomentose peduncles. The simultaneous presence of buds and flowers on the branches increases its originality during the flowering period. White flowers with pale yellow anthers of *Crataegus submollis* with a diameter of 2.5 cm are collected by 10-15 pieces in numerous inflorescences that look bright against the background of bright green foliage. *Padus virginiana* blooms profusely in descending inflorescences of 15-25 white flowers against a background of dark green foliage.

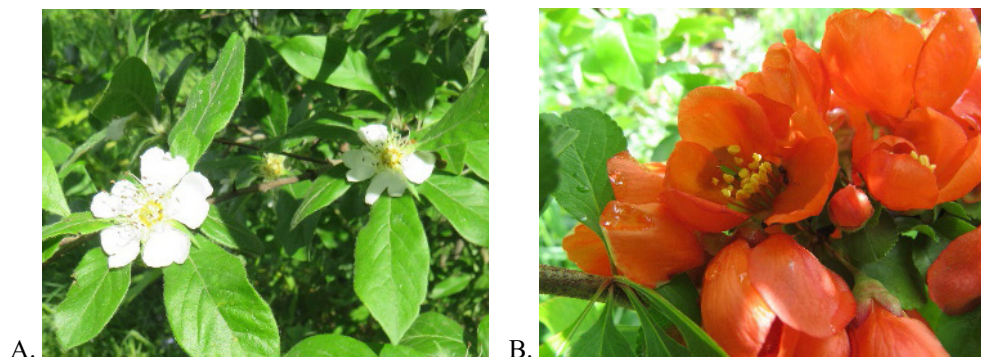


Fig. 1. Flowering: A. *Mespilus germanica*; B. *Chaenomeles Maulei*

4 Conclusion

The flowering peculiarities' analysis of non-traditional fruit crops of the Rosaceae family showed the possibility of their integrated use in selection and greening in the conditions of the Central part of Russia.

The flowering calendar compiled based on the conducted phenological observations shows different dates of objects' flowering start, which makes it possible to use them not only as fruit, but also as ornamental plants when creating parks and gardens of continuous flowering. Non-traditional fruit crops of Far Eastern (*Chaenomeles Maulei* and *Malus niedzwetzkyana*) and North American (*Crataegus submollis* and *Padus virginiana*) ecological and geographical origin have the highest flowering ornamentality. Of these, *Chaenomeles Maule* has the longest flowering period (more than 20 days).

A consistently high degree of flowering (4.5-5.0 points) was observed in twelve objects, which determines the prospects of their use in selection as sources of certain economically valuable traits: early flowering terms (*Malus prunifolia* and *Sorbus aria*), long flowering (*Chaenomeles Maulei*, *Malus prunifolia* and *Rosa canina*), high ornamental flowering degree (*Chaenomeles Maulei*, *Malus niedzwetzkyana*, *Crataegus submollis* and *Padus virginiana*).

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