Arctic
Environmental
Research

Arctic Environmental Research 18(1): 37–44
UDC 582.734.3: 581.522
DOI 10.17238/issn2541-8416.2018.18.1.37

Research Article

Development of introduced species *Malus* Mill. (Rosaceae Adans.) in South Karelia

IT Kishchenko[1]

1 *Petrozavodsk State University (Petrozavodsk, Russian Federation)*

Corresponding author: *Ivan Kishchenko* (ivanki@karelia.ru, botanika@psu.karelia.ru)

Academic editor: *Boris Filippov* ♦ **Received** 14 December 2017 ♦ **Accepted** 16 February 2018 ♦ **Published** 30 March 2018

Citation: Kishchenko IT (2018) Development of introduced species *Malus* Mill. (Rosaceae Adans.) in South Karelia. Arctic Environmental Research 18(1): 37–44. https://doi.org/10.17238/issn2541-8416.2018.18.1.37

Abstract

This study contains findings of research carried out at the Botanical Garden of Petrozavodsk State University (South Karelia, central taiga subzone) in April – October in the period from 1986 to 2012. The subjects of the studies were introduced plants of three species of *Malus* Mill.: dwarf apple – *Malus baccata* (L.) Borkh., wild apple – *Malus sylvestris* Mill., and Niedzwetzky's apple – *Malus niedzwetzkyana* Dieck. ex Koehne. Phenological observations were carried out once in 3 days by the N. Bulygin technique (1979). The phenophase was considered to have occurred if it was observed in at least 30% of the shoots of all specimens of the species under study. All samples were checked for compliance with the normal probability law. The correlation coefficients and differences between the mean values were verified to determine their reliability. Elementary statistics obtained demonstrate, among other things, that the experiment's accuracy rate is fairly high (4–6%), while the variation coefficient is small (18–22%). It was found that *M. baccata* trees begin and end most of their phenophases approximately 5–10 days earlier than the other studied species. Furthermore, in the beginning and middle of the growing period, phonological phases of *M. baccata* proceed at colder weather compared to the other studied *Malus* species. At the end of the growing period, these differences among the species level off. Of all the studied climatic factors, air temperature has the most measurable positive influence on the development of *Malus* species in Karelia. Daily average air humidity and precipitation have a less prominent influence on epy phenophases of the studied *Malus* species. The course and strength of such influence depend on the peculiarities of the phenophase itself. All the studied introduced *Malus* species show a high degree of introduction prospect (82–93 points) and can be successfully used in Karelia for gardening and landscaping purposes.

Keywords

introduction, development, *Malus*, ecological factors, South Karelia

Introduction of fruit species has always been important, especially in regions where such plants are scarce. Most indigenous species of woody plants in the taiga zone of Russia are extremely sensitive to progressive environmental pollution (Shkutko 1991). At the same time, many species of deciduous trees, including *Malus* Mill. species, are fairly tolerant to pollution of air with gas and smoke. This fact suggests their possible introduction and assessment of such introduction (Lapin 1967a, b, Plotnikova and Gubin 1986, Kovaleva and Namzalov 2009, Buntsevich et al. 2012, Repykh and Popova 2015, Kondratenko and Kondratenko 2015, Loginov 1980).

One key criterion for introduction is the degree of conformity of growth rhythm and development of the plant to the changes in ecological factors Kondratenko and Kondratenko 2015). Seasonal development rhythm acts as the integral criterion that qualifies adaptation of plants to the environmental conditions and correspondence of such conditions to the biology of a species (Lapin 1967b, Loginov 1980). Russian literature does not pay much attention to the specifics of seasonal development of deciduous trees (Shestopalova 1982).

The studies were carried out to identify the specifics of development of *Malus* introduced species in Karelia in order to assess the degree of their adaptation to the local climate and prospects for their use in gardening and landscaping. There is no record of any earlier studies of this kind in Karelia.

Materials and methods

The studies were carried out over a 27-year period (1986–2012), from April through October, at the Botanical Gardens of Petrozavodsk State University located on the north shore of the Petrozavodsk Bay of Lake Onega (central taiga subzone). The subjects of the studies were introduced plants of three species of *Malus* Mill.: dwarf apple – *Malus baccata* (L.) Borkh., wild apple – *Malus sylvestris* Mill., and Niedzwetzky's apple – *Malus niedzwetzkyana* Dieck. ex Koehne.

Trees of each species were planted in groups at the age of 6–8 years, 15–30 specimens of each. A description of the study subjects is provided in Table 1.

Phenological observations were carried out once in 3 days by the N. Bulygin technique (Bulygin 1979). These observations served to record the beginning of such phenophases as swelling and bursting of vegetative and reproductive buds, beginning and end of shoot growth, their segregation and end of growth, leaf colouring and shedding, corking of shoots, blossoming, fruit inception, ripening and drop. The phenophase was considered to have occurred if it was observed in at least 30% of the shoots of all specimens of the species under study.

Meteorological data was acquired from Sulazhgora weather station (Karelian Hydrometeorological Observatory) located 3 km south-west of the Botanical Gardena. All samples were checked for compliance with the normal probability law. The correlation coefficients and differences between the mean values were verified to determine their reliability. Elementary statistics obtained demonstrate, among other things, that the experiment's accuracy rate is fairly high (4–6%), while the variation coefficient is small (18–22).

Findings

The studies demonstrated that the rhythm of seasonal development of the studied *Malus* species has certain peculiarities. Different species have different phenophase occurrence dates (phenodates) and different durations of such phenophases.

A review of statistical analysis data showed that the long-time phenodate error is insignificant and normally does not exceed 2–3 days (Table 2). According to N.V. Shutko (Shkutko 1991), small phenodate error indicates that introduced species are highly capable of adapting to new climates.

The studies helped establish that the rhythm of seasonal development of the studied *Malus* species has certain peculiarities. Based on the long-time average data, vegetative buds begin swelling fastest (20 IV) on *M. baccata,* while for *M. niedzwetzkyana,* this phenodate occurs only on 7 V.

The earliest date of bursting of vegetative buds is also typical of *M. baccata* (6 V), and the latest phenodate was recorded for *M. niedzwetzkyana* (14 V).

Table 1. Description of subjects of study

Species	Young plant growing site	Home land	Age, years	Height, m	Crown diameter, m	Crown height, m
Malus baccata (*winter* hardy)	St. Petersburg, Krasnoe Selo nursery	North China	53	8.0	3.6	7.1
M. sylvestris	–	European Russia, northern boundary up to the limits of the Vologda Region	53	4.7	2.8	3.9
M. niedzwetzkyana	–	Tien Shan mountains	46	6.3	3.9	5.9

Linear growth of shoots on *M. sylvestris* (28 V) begins 6–9 days later than on the other studies species. Shoots growth on *M. baccata* ends (9 VI) 9–11 days earlier than on the other two species. Leaf growth on *M. sylvestris* ends (28 VI) 7–20 days later than on the other two species. Colouring of fading leaves begins for *M. baccata* as soon as 5 VIII, for *M. niedzwetzkyana* –18 VIII, and for *M. sylvestris* –24 VIII. Thus, *M. baccata* has 1–2 weeks longer than the other two species to enter the deep dormancy phase. Leaf shedding on *M. baccata* (20.VIII) also begins earlier (10 days) than on the other species.

Reproductive buds begin swelling on *M. niedzwetzkyana* shoots as early as in mid-May (12 V), while for the other species this phenodate occurs 4–12 days later. Bursting of reproductive buds on *M. niedzwetzkyana* (15 V) also occurs 2 weeks earlier than on the shoots of the other species. Blossoming of *M. baccata* begins on 8 VI, and the other species enter this phase 10–13 days later. The blossoming phenophase ends earliest for *M. baccata* (11 VI), and latest for *M. niedzwetzkyana* (25 VI).

Fruit inception on *M. sylvestris* occurs on 11 VI, and on the other species – on 19–23 VI. Fruits on *M. sylvestris* grow to ripe size in mid-July (16 VII), and on *M. niedzwetzkyana* – only two weeks later (30 VII). *M. baccata* is the first species to enter the fruit ripening phase (13 VIII), while *M. niedzwetzkyana* enters this phenophase only in late August (27 VIII). All the studied species begin dropping ripe fruits around the same dates in mid-October (13–22 X).

Studies by a number of authors (Shkutko 1991, Lapin 1967a, Plotnikova and Gubin 1986, Loginov 1980) discovered that earlier phenophase occurrence datesindicate a better capability to adapt to a new environment. In these studies, *Malus baccata* is represented by a frost-resistant variety, which is most likely the reason for its earlier dates of occurrence of most phenophases compared to the other studied species and its higher degree of adaptation to the conditions of a new home land.

Fairly close phenodates of *Malus baccata* in the East Transbaikal region were discovered by S.V. Kovaleva and B.B. Namzalov (Kondratenko and Kondratenko 2015).

Authors of numerous studies (Lapin 1967a, Potapova 1985, Plotnikova and Gubin 1986) have convincingly demonstrated that peculiarities of development of different plant species are predetermined by differences in their tolerance to ecological factors. For instance, after establishing the range of tolerance of major phenophases to ecological factors, one can judge the degree of adaptation of the species to the conditions of its habitat.

Analysis of the state of the environment at the beginning of phenophases revealed a very strong year-by-year variability of relative air humidity, precipitation and total solar radiation values. At the same time, air temperature values at the time of occurrence of each next phenophase during the study period were very similar, which speaks of a much stronger influence of this climatic factor on development of the plants. Similar conclusions regarding other species of deciduous introduced species were previously drawn by A.N. Kolesnichenko (Kolsnichenko 1985) and E.Sh. Belorusets and V.K. Gorb (Belorusets and Gorb 1900).

Table 2. Seasonal development statistics for *Malus* species

Phenophase and statistical criteria		*Malus baccata*	*Malus sylvestris*	*Malus niedzwetzkyana*
Swelling of vegetative buds	M	20 IV	27 IV	7 V
	mM	2.3	0.7	0.9
Bursting of vegetative buds	M	6 V	12 V	14 V
	mM	4.3	3.4	3.1
Beginning of shoots growth	M	19 V	28 V	22 V
	mM	3.0	0.8	3.0
End of shoots growth	M	9 VI	20 VI	18 VI
	mM	5.2	7.4	5.9
End of leaf growth and maturing	M	21 V	28 V	18 V
	mM	0.9	1.1	0.5
Leaf colouring	M	5 VIII	24 VIII	18 VIII
	mM	3.7	1.0	6.1
Leaf shedding	M	20 VIII	31 VIII	2 X
	mM	3.2	3.3	0.7
Swelling of reproductive buds	M	16 V	24 V	12 V
	mM	1.3	4.0	4.6
Bursting of reproductive buds	M	30 V	29 V	15 V
	mM	0.8	4.7	4.9
Start of blossoming	M	8 VI	21 V	18 IV
	mM	0.7	4.5	5.2
End of blossoming	M	11 VI	18 VI	25 VI
	mM	3.7	6.3	5.9
Fruit inception	M	19 VI	11 VI	23 VI
	mM	1.2	6.2	5.7
Fruits grow to ripe size	M	25 VII	16 VII	30 VII
	mM	2.3	5.8	3.4
Fruit ripening	M	13 VIII	17 VIII	27 VIII
	mM	3.5	3..3	4.5
Fruit drop	M	13 X	17 X	22 X
	mM	2.1	10.2	2.3

Note: M – mean phenodate; mM– mean phenodate error, days.

Table 3 demonstrates that swelling of vegetative buds on *M. sylvestris* and *M. baccata* begins as soon as the daily average air temperature rises to +4.9–5.2 °C. Occurrence of this phenophase on *M. niedzwetzkyana* requires much warmer weather (+8.0 °C). Bursting of vegetative buds on the studied species occurs when the air temperature rises to +7.8…+10.0 C.

Linear growth of shoots on the studied *Malus* species begins at an air temperature of +9.9…+11.6 °C. This phenophase on *M. baccata* ends at a temperature of around +9.3, and on *M. niedzwetzkyana* – at +12.9 °C.

Leaf growth ends when the air temperature drops to +11.4…+13.7 °C. Colouring of fading leaves on *M. sylvestris* begins when the air temperature drops

Table 3. Long-time average daily values of ecological factors during phenoplases of *Malus* [x)] species

Phenophase	Environmental parameters	*Malus baccata*	*Malus sylvestris*	*Malus niedzwetzkyana*
Swelling of vegetative buds	T	4.9	5.2	8.0
	H	57	67	58
	P	0.2	2.4	0.7
	R	350	453	801
Bursting of vegetative buds	T	7.8	8.0	10.0
	H	60	56	48
	P	0.3	1.0	0.6
	R	400	432	411
Beginning of shoots growth	T	9.9	10.2	11.6
	H	50	65	53
	P	2.0	1.6	0.6
	R	459	675	856
End of shoots growth	T	9.3	10.6	12.9
	H	55	57	63
	P	0.6	1.8	3.2
	R	314	623	1003
End of leaf growth and maturing	T	13.7	11.4	11.6
	H	51	57	59
	P	1.4	1.6	1.1
	R	290	544	634
Leaf colouring	T	6.6	11.8	10.5
	H	49	68	73
	P	1.9	1.9	0.7
	R	173	287	354
Leaf shedding	T	4.3	5.6	4.8
	H	43	73	77
	P	0.8	2.2	0.8
	R	260	767	1078
Swelling of reproductive buds	T	10.1	8.0	6.9
	H	59	60	38
	P	0.8	1.3	0.1
	R	297	421	556
Bursting of reproductive buds	T	14.0	8.4	6.9
	H	58	46	32
	P	2.8	0.8	1.6
	R	459	611	556
Start of blossoming	T	14.7	15.6	16.7
	H	53	46	32
	P	3.7	1.2	1.3
	R	454	765	844

End of blossoming	T	14.0	15.0	15.6
	H	58	48	38
	P	0.7	2.0	1.0
	R	250	467	989
Fruit inception	T	18.5	17.3	18.6
	H	64	58	34
	P	1.9	0.6	0.3
	R	402	621	708
Fruits grow to ripe size	T	18.4	16.5	16.3
	H	78	80	93
	P	0.1	2.4	2.0
	R	0.0	0.2	0.6
Fruit ripening	T	15.9	14.6	12.3
	H	50	53	40
	P	3.2	1.1	0.2
	R	166	354	468
Fruit drop	T	4.9	3.4	3.8
	H	45	46	51
	P	1.5	0.2	1.2
	R	556	432	322

[x)] Note. T – air temperature, °C; APT – accumulated positive temperatures, °C; H – relative air humidity, %; P – precipitation rate, mm; R – solar radiation, cal./cm^2.

to +11.8 °C, and on *M. baccata* – to +6.6 °C. Leaf shedding on all the studied species begins as soon as the air temperature goes down to +4.3…+5.6 °C.

Swelling and bursting of reproductive buds begins for *M. baccata* at the highest air temperature values (+10.1…+14.0 °C), and for other species – at +6.9…+8.4 °C. The blossoming phase begins and ends for different species at similar temperature values of around +14.0…+16.7 °C.

Fruit inception and ripening occurs when the air temperature is at its maximum over the growing period (+14.3…+18.5 °C). Fruits begin to fall when the air temperature drops to +3.4…4.9 °C.

Discussion

The above findings speak to the fact that phonological phases of *M. baccata* in the beginning and middle of the growing period begin and proceed at lower temperatures than the same phases of the other studied *Malus* species. At the end of the growing period, these differences among the species level off.

A correlation analysis was carried out to establish the course, form and strength of the relationship between the ecological factors and phenodates. It was found that the course and strength of influence of ecological factors on the development of plants may differ considerably depending on the biological peculiarities of a certain species, the specifics of the phenophase and the period when the plants are exposed to certain ecological factors.

The findings of the studies imply that this correlation is linear and valid in almost every case. Also, the correlation can be both positive and negative, and the force of the influence depending on the species and phenophase can vary widely (r= +0.4…+0.8). Correlation analysis data shows that air temperature has a strong positive influence on all the examined phenophases except leaf growth and colouring, as well as growth of fruits to ripe

Table 4. Assessment of *Malus* introduction prospect

Species	Annual maturing of shoots	Weather hardiness	Habit preservation	Shoot-forming capability	Regular growth of axial shoots	Generative reproduction capability	Capability to reproduce in plantation	Final prospect score
Malus baccata	16	16	8	4	5	25	8	82
M. sylvestris	19	19	10	5	5	25	10	93
M. niedzwetzkyana	18	18	9	4	5	25	7	86

size. The prominent influence of air temperature on the phenology of *Malus* species in the taiga zone was previously discovered by S.V. Kovaleva and B.B. Namzalov (Kovaleva and Namzalov 2009).

Daily average air humidity during the phenophases of the studied species also has sizeable effects (r = [0.4…0.8]). It has a positive influence on the dates of occurrence of reproductive buds swelling and bursting, blossoming and leaf shedding phenophases, and a negative influence on the other phenophases. Air humidity has a moderate positive influence only on the phases of shoots growth end and stiffening, end of blossoming and fruit inception. The influence of precipitation on the phenophases is identical. The fact that occurrence and duration of phenophases depend on humidity has also been documented by other researchers (Repykh and Popova 2015, Kondratenko and Kondratenko 2015).

The studies failed to discover any reliable proof of solar radiation's influence on the phenophases of the studied species.

The studies revealed that dissimilarities among the species are insignificant across the entire range of introduction criteria (Table 4). For example, the lowest grade of stalk maturing (16 points out of 20) is typical of *M. baccata,* while for *M. sylvestris* this criterion has the highest grade (19 points).

Maximum winter hardiness grade is 25 points, which none of the studied species reach. *M. sylvestris* was found to have the highest grade for this criterion (19 points). The highest grade for habit preservation (10 points) was documented only for *M. sylvestris*. The highest shoot-forming capability grade was also recorded only for this species (5 points). All the studied species were found to have the highest grade for regular growth of axial shoots (5 points).

Maximum generative reproduction capability grade (25 points) was documented for all the *Malus* species. Capability to reproduce in plantation has a maximum grade of 10 points, which was recorded only for *M. sylvestris.*

The above data was used for a summary assessment of the introduction prospects for the studied introduced species. All the studied *Malus* species were found to have high prospect rates – 82–93 points.

Takeaways:

1. *M. baccata* as the most adapted and frost-resistant species, begins and ends almost all its phenophases approximately 5–10 days earlier than the other studied species. Furthermore, in the beginning and middle of the growing period, phonological phases of *M. baccata* proceed at colder weather compared to the other studied *Malus* species. At the end of the growing period, these differences among the species level off.
2. Of all the studied climatic factors, air temperature has the most measurable positive influence on the development of *Malus* species in Karelia. Daily average air humidity and precipitation have a less

prominent influence on the phenophases of the studied *Malus* species. The course and strength of such influence depend on the specifics of the phenophase itself.

3. All the studied introduced *Malus* species show a high degree of introduction prospect (82–93 points) and can be successfully used in Karelia for gardening and landscaping purposes.

References

- Belorusets ES, Gorb VK (1900) Lilac [Siren]. Vintage, Kiev, 176 pp.
- Bulygin NE (1979) Phenological observations over woody plants [Fenologicheskie nablyudeniya nad drevesnymi rasteniyami]. 97 pp.
- Buntsevich LL, Kostyuk MA, Paletskaya EN (2012) Fruit growing and Russian grapes [Plodovodstvo i yagodovodstvo Rossii]. Vol. 31(1.1), 55–61.
- Kolsnichenko AN (1985) Seasonal rhythms of exotic species of wood development [Sezonnye ritmy razvitija drevesnyh introducentov]. Ohrana, izuchenie i obogashhenie rastitelnogo mira [Guard, study and enrichment of the plant world] (Kiev) 12: 53–59.
- Kondratenko TYe, Kondratenko PV (2015) Phenology of apple tree (*Malus domestica* Borkh.) In Kyiv Region in the context of climate change [Phenology of apple tree (*Malus domestica* Borkh.) in Kyiv Region in the context of climate change]. Plant Varieties Studying and Protection [Plant Varieties Studying and Protection] 1–2(26–27): 49–53. https://doi.org/10.21498/2518-1017.1-2(26-27).2015.55911
- Kovaleva SV, Namzalov BB (2009) Some features of the *Malus* baccata apple tree development in the city of Chita (Eastern Transbaikalia) [Nekotorye osobennosti razvitiya yabloni *Malus baccata* v usloviyakh goroda Chita (Vostochnoe Zabaykale)]. Vestnik Buryatskogo gosudarstvennogo universiteta [Bulletin of the Buryat State University] 4: 118–121.
- Lapin PI (1967a) Seasonal rhythm of development of woody plants and its importance for the introduction. [Sezonnyj ritm razvitija drevesnyh rastenij i ego znachenie dlja introdukcii]. Bjul. GBS AN SSSR [Bul. GBS USSR] 65: 12–18.
- Lapin PI (1967b) Seasonal rhythm of development of woody plants and its significance for introduction [Sezonnyy ritm razvitiya drevesnykh rasteniy i ego znachenie dlya introdukcii] Byul. GBS AN SSSR [Bul. Head of the Academy of Sciences of the USSR] 65: 12–18.
- Loginov VB (1980) To the method of constructing specific theories Introductions [K metodike postroenija chastnyh teorij introdukcii] Teorii i metody introdukcii rastenij i zelenogo stroitel'stva. Mater. Resp. konf. Kiev [Theory and methods of introduction of plants and green building. Mater. Resp. conf. Kiev.] 58–60.
- Plotnikova LS, Gubin EM (1986) Growth and development of woody plants in the culture [Rost i razvitie drevesnyh rastenij v kulture] Sezonnyj ritm introducirovannyh drevesnyh rastenij flory SSSR. GBS AN SSSR [Seasonal rhythm of introduced woody plants of the USSR flora . GBS USSR], 127–149.
- Potapova SA (1985) Dynamics of shoot growth of introduced species of pine [Dinamika rosta pobegov introducirovannyh vidov sosen]. Bjul. GBS AN SSSR [Bul. GBS USSR] 137: 28–31.
- Repykh MV, Popova NN (2015) Selection of apple plants on the basis of phenology on the lower tarris of the Botanical Garden. Sun. M. Krutovsky [Otbor matochnykh rasteniy yabloni po fenologii na nizhney tarrase Botanicheskogo sada im. Vs. M. Krutovskogo]. Vestnik Krasnoyarskogo agrarnogo universiteta [Bulletin of the Krasnoyarsk Agrarian University]1: 28–31.
- Shkutko NV (1991) Conifer Belarus [Hvojnye Belorussii]. Nauka,Moscow, 263 pp.
- Shestopalova VV (1982) Results of the introduction of pine (*Pinaceae* Lindl.) on the Central Russian Upland and prospects of their use. cand. biol. sci. diss. [Itogi introdukcii sosnovyh (*Pinaceae* Lindl.) na Srednerusskoj vozvyshennosti i perspektivy ih ispolzovanija. Kand. biol. nauk. diss.]. Kiev, 22 pp.