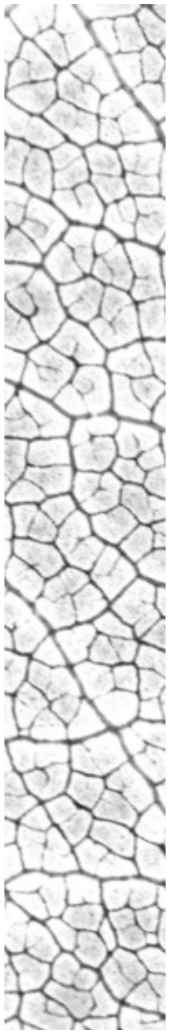

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Seasonal development of introduced apple-tree varieties under arid conditions of Western Kazakhstan

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Abstract
For the first time the article presents perennial statistically processed results of pheno-observations for 11 apple varieties introduced into the Mangyshlaksky Experimental Botanical Garden, located in the west of Kazakhstan, whose natural conditions are characterized by sharp fluctuations of air and soil temperature in both summer and winter periods, aridity and high content of readily soluble salts in soil with underlying slab of Sarmatian limestone. They determined the average phenodates of the main phenophases and the average duration of growth and development periods among apple varieties, and their variability was revealed. It was noted that generative organs are characterized by significantly lower variability than vegetative ones. In local conditions, there was a significant decrease in the fruiting period, the decrease of yield and the average weight of fruits. The most resistant and productive varieties were selected. The work was conducted on the grant project topic "Introduction of apple tree promising varieties into the culture in arid regions of Western Kazakhstan".

Keywords: apple tree, varieties, introduction, arid conditions, salinization, phenodates, phenophases, growth and development rhythms, the growth of shoots, yield, fruit weight, variability, resistance

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INTRODUCTION

Mangistau is located on the eastern shore of the Caspian Sea (Western Kazakhstan). The climate is sharply continental, extremely dry (an average annual rainfall makes 108-180 mm), hot (up to 47 °C) in summer and rather cold in winter (down to - 18 °C, absolute minimum - 34 °C). The soils are brown and gray-brown, characterized by a high degree of salinization and close occurrence to the hard rock surface (Sarmatian limestone, etc.). The nature of vegetation is typically desert one, with the predominance of semi-shrub saltwort and wormwood, ephemers and ephemeroids during springtime. Trees are absent in local nature as a life form (Borovsky et al. 1974). The vast family of Rosaceae is represented very poorly in the local flora. There are only 7 species from 5 genera (Crataegus L., Potentilla L, Rosa L., Rubus L., Spiraea L.), which are rare ones (State cadastre of plants in Mangystau region 2006). Therefore, the cultivation of woody plants, including apple trees, is possible only with special agricultural practices and the methods of introduced species maintaining (the creation of a drainage system that eliminates secondary soil salinity; watering at the rate of 350–400 t/ha 4–6 times a month, from May to September; introduction of organic fertilizers and mulching with manure and sawdust for sowing furrows and tree trunks; the excavation of deep planting holes and trenches with full replacement of soil and ground in the areas with close bedding of bedrock) (Kosareva 2012).

According to historical information, small gardens, including apple tree gardens, had been grown on the peninsula since the 19th century on separate oasis sites with spring waters (Bulgakov et al. 2018, Kosareva 1984). In the 1980s, we surveyed fruit plantations with the total area of about 25 hectares in the mountainous part of the Mangyshlak Peninsula, where the main species were apricot and apple trees.

The introduction of apple trees in the Mangyshlak Experimental Botanical Garden began in 1974, initially wild species of Malus Mill. were attracted and studied, and the attraction and the study of varietal apple trees have been performed actively since 2006-2007.

Currently, the collection contains 39 species and 28 varieties of apple trees (Kosareva et al. 2018).

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Table 1. Average phenodates of introduced apple tree varieties

Vegetative organs									
Variety name	Bud opening ($П_{ч2}$)	Leaf separation ($Л_1$)	Shoot growth		Growth duration (days)	Lignification		Leaf fall ($Л_5$)	Vegetation duration (days)
			beginning ($Пб_1$)	end ($Пб_2$)		beginning ($О_1$)	end ($О_2$)		
Askar	26.03±5.3	29.03±3.4	28.04±2.4	21.07±6.4	83.4±7.8	16.07±7.9	26.08±2.1	18.11±2.0	234.3±4.3
Asya	27.03±5.1	30.03±3.1	27.04±2.7	21.07±6.0	85.4±8.0	16.07±8.5	21.08±4.2	18.11±2.1	233.6±3.9
Voskhod	25.03±6.1	31.03±2.9	27.04±2.8	20.07±6.0	84.1±8.0	25.07±7.4	22.08±3.4	18.11±2.3	231.6±4.3
Zailiyskoye	25.03±4.6	30.03±2.4	28.04±2.4	21.07±6.5	81.9±8.2	27.07±8.5	26.08±1.4	19.11±1.9	234.0±3.9
Prime Golden	01.04±5.6	02.04±3.1	27.04±1.6	03.07±6.9	84.3±7.8	17.07±8.0	27.08±1.5	18.11±2.0	232.3±4.4
Kandil – Sinap	29.03±5.3	29.03±2.8	01.05±2.7	25.07±6.8	85.3±8.2	20.07±8.4	28.08±1.6	19.11±2.1	235.0±4.0
Mantet	24.03±4.6	29.03±2.5	01.05±2.4	24.07±6.9	83.3±7.6	18.07±8.6	27.08±1.0	17.11±0.9	232.3±3.1
Rennet Burkhardta	28.03±4.4	31.03±3.2	28.04±3.1	21.07±6.0	84.3±8.3	16.07±8.2	27.08±2.0	19.11±2.6	233.0±3.9
Saltanat	27.03±5.1	30.03±2.7	27.04±2.9	22.07±6.0	85.6±8.2	18.07±9.4	23.08±4.3	16.11±0.7	230.6±3.2
Stolovka	28.03±4.9	31.03±3.1	28.04±2.7	03.07±15.2	80.7±8.7	15.08±7.8	25.08±2.2	18.11±2.0	232.4±3.6
Florina	26.03±8.2	30.03±3.1	30.04±2.7	24.07±6.7	84.7±7.8	18.07±8.2	27.08±1.5	19.11±2.2	234.0±4.6

Generative organs									
Variety name	Bud opening ($Ц_2$)	Budding ($Ц_3$)	Flowering		Flowering period (days)	Fruit ripening ($Пл_3$)		Fruit fall ($Пл_4$)	Fruit ripening period (days)
			beginning ($Ц_4$)	end ($Ц_5$)		beginning	end		
Askar	07.04±2.3	13.04±5.2	20.04±2.0	01.05±1.7	11.7±1.0	11.08±6.4	22.08±6.3	21.08±6.0	12.3±1.6
Asya	29.03±5.1	15.04±2.9	19.04±1.9	30.04±1.4	11.3±1.3	08.08±7.1	24.08±6.9	24.08±7.0	17.0±5.4
Voskhod	05.04±5.6	15.04±1.2	21.04±1.7	02.05±1.7	11.0±1.4	06.08±4.8	16.08±5.1	16.08±4.6	15.2±1.2
Zailiyskoye	08.04±2.3	14.04±1.7	20.04±1.9	30.04±1.7	10.1±1.0	08.08±7.0	17.08±8.0	16.08±6.4	13.2±2.0
Prime Golden	13.04±2.8	14.04±1.5	21.04±1.6	30.04±1.2	9.0±1.0	08.08±4.3	15.08±2.8	16.08±2.9	11.3±2.7
Kandil – Sinap	10.04±3.1	16.04±2.7	20.04±2.2	01.05±2.6	11.3±0.9	31.07±4.3	15.08±3.8	19.08±3.3	15.3±1.7
Mantet	05.04±5.7	15.04±2.2	22.04±2.1	02.05±1.6	9.9±1.1	23.07±4.9	05.08±3.3	08.08±2.9	12.3±1.9
Rennet Burkhardta	09.04±2.1	15.04±1.9	20.04±1.8	30.04±1.5	9.7±0.7	31.07±5.1	07.08±3.8	08.08±3.7	9.2±1.5
Saltanat	08.04±2.1	15.04±2.0	20.04±2.0	30.04±1.5	10.1±1.1	04.08±6.8	16.08±5.7	19.08±5.5	12.3±1.9
Stolovka	09.04±2.3	15.04±1.6	20.04±1.5	30.04±1.4	9.9±0.9	26.07±4.9	10.08±2.7	14.08±2.2	14.9±2.8
Florina	08.04±2.0	15.04±2.2	21.04±2.0	01.05±1.7	10.0±1.0	04.08±6.8	19.08±5.3	23.08±5.1	15.1±2.6

OBJECTS FOR STUDY AND STUDY METHODS

The objects of the study were 11 apple varieties located in Kazakhstan (Asya, Askar, Voskhod, Zailiyskoye, Prime Golden, Kandil – Sinap, Mantet, Rennet Burkhardta, Saltanat, Stolovka, and Florina). The saplings of these varieties, grafted on annual seedlings of Sievers apple tree, were brought from Issyk Arboretum nursery (Almaty) and at the same time planted in early April 2010 on a specially prepared site, where they removed compacted salted topsoil, made the ground holes of 1.5 x 2 meters with the depth of 1 meter, filled them with a specially prepared substrate (the mixture of non-saline sandy soil with manure and sawdust). The initial soil state of the site is medium loamy, slightly saline, medium saline, small-profile, with close bedding to the surface of Sarmatian limestone. The apple trees were planted according to 5x3 meter scheme, with a free-form crown, 20 copies of each variety. Watering was carried out in tree trunks from 20 to 25 times during the growing season, the irrigation rate was 45 - 46 l/m^2.

The growth and development observations of apple tree varieties were carried out according to generally accepted methods (The methods of introduction studies in Kazakhstan 1987, Dzhangaliev et al. 1961, Kosareva and Lyubimov 1987), taking into account the experience of apple tree species introduction (Kosareva and Lyubimov 1987). The growth dynamics of the shoots was determined by decadal measurements of terminal growth shoots. The measurements of shoot growth for statistical processing were carried out by 10 model trees of each variety, 10 shoots from each tree (Nourizadeh et al. 2015, Udolskaya 1976). The mass of fruits and yields were determined by the weight method (the harvest from one medium tree during 2016–2018, the mass of 30 fruits of each variety), using the statistical programs Statgraphics Centurion XV.I. The computer program FENO-S developed in MEBG (Chamkouri et al. 2015) was used for the mathematical processing of long-term pheno-observation results (2011–2018).

RESULTS

The conduct of perennial pheno-observations is the basis of introduction work, which allows you to identify the rhythms of plant growth and development in new climatic conditions. The average phenodates of 11 introduced varieties of apple trees are presented in **Table 1**. The dehiscence of vegetative buds was observed at the end of March (24.03 ± 4.6 - 29.03 ± 5.3). Relatively earlier dehiscence of vegetative buds was observed among the varieties Mantet, Voskhod, Zailiyskoye, the latest dates of this phenophase occurrence is observed among Prime Golden variety (01.04 ± 5.6). The separation of leaves was observed during the period from 29.03 ± 3.4 to 02.04 ± 3.1. The earliest phenodates are among the varieties Askar, Kandil - Sinap, Mantet, the latest ones - Prime Golden variety. The shoot growth phase began at the end of April - the first days of May (from 27.04 ± 2.9 to 01.05 ± 2.7). Asya, Saltanat, Prime Golden varieties had a relatively early start of the shoot growth. Prime Golden and Stolovka varieties had the earliest end of shoot

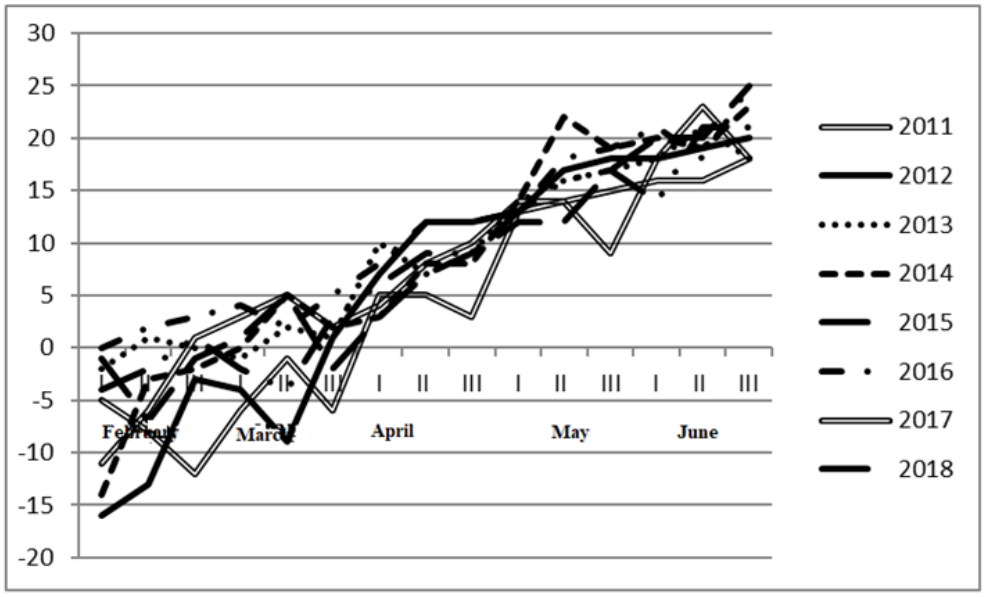

Fig. 1. Minimum decadal air temperatures in 2011 - 2018

growth (03.07 ± 6.9 - 03.07 ± 15.2). In most varieties, shoot growth ended during the period from 20.07 ± 6.0 to 25.07 ± 6.8. The average period of shoot growth varied from 80 to 85 days. As can be seen from **Table 1**, by "vegetative bud opening" phenophase the difference in phenodates between varieties was 8 days, the difference by phenophase "leaf separation" and "the beginning of shoot growth" made 4-5 days. The biggest difference between varieties was marked by the phenophase "the end of shoot growth" - up 22 days.

Since all varieties were grown on the same agricultural background, it should be assumed that the duration of shoot growth depended also on the biological characteristics of each particular variety. Average phenodates of flower buds opening were noted during the period from 29.03 ± 5.1 (Asya variety) to 13.04 ± 2.8 (Prime Golden variety), budding - from 13.04 ± 5.2 (Askar variety) to 16.04 ± 2.7 (Kandil – Sinap variety). The average time of flowering beginning makes from 19.04 ± 1.9 to 22.04 ± 2.1, the end of flowering - from 30.04 ± 1.5 to 02.05 ± 1.7. As can be seen from **Table 1**, the difference between the varieties by the average periods of budding phenophase passage, the beginning and the end of flowering were only 2 - 3 days, while for the phase of "flower bud opening" this period made up to 15 days. The average duration of flowering was observed within 9–11 days, i.e. the difference between varieties made 2 days.

Thus, the varieties of Kazakhstan origin Askar, Asya, Zailiyskoe, as well as the Canadian variety Mantet, which was characterized, however, by late flowering should be considered in our conditions as relatively earlier varieties in terms of the growing season start. The American variety Prime Golden and the Crimean variety Kandil - Sinap are relatively later varieties concerning the growing season beginning in our conditions. However, they did not reveal a clear dependence between the beginning of the growing season and the geographical origin of a particular variety. Besides, the difference in vegetation beginning terms, the growth of shoots and flowering is not critical for the development of apple trees in our conditions, since the air temperature in the second half of March, and in some years in February, did not drop to minus temperatures during long period observations (Kosareva and Dinova 2016) (**Fig. 1**).

The periods of fruit ripening differed in accordance with the biological characteristics of varieties. The early summer and summer varieties Mantet (23.07 ± 4.9 - 05.08 ± 3.3) and Rennet Burkhardta (31.07 ± 5.1 - 07.08 ± 3.8) ripened first, the latter was the late winter Asya and the autumn variety Askar (08.08 ± 7.1 - 24.08 ± 6.9). In the first - second decade of August, the Prime Golden, Zailisky and Saltanat varieties ripened (late autumn varieties). As they already noted (Kosareva et al. 2018), in our conditions, the shift of fruit ripening phenophase to earlier dates is observed, which is especially noticeable in late autumn and winter varieties, but the sequence of fruit ripening has been preserved in different varieties. The average duration of fruit ripening ranged from 9.2 ± 1.5 (Rennet Burkhardta) to 17.0 ± 5.4 days (Asya). For most varieties, fruit ripening was observed during 12-15 days. The lignification of shoots, necessary for successful wintering, began in the second half of July, among the varieties Askar, Asya, and Rennet Burkhardta (16.07 ± 8.5) earlier than among others. The latest lignification was observed for Stolovka (15.08 ± 7.8). In the third decade of August, there was a complete lignification of the shoots in all varieties (21.08 ± 4.2 - 28.08 ± 1.6). The lignification lasted for 40 days

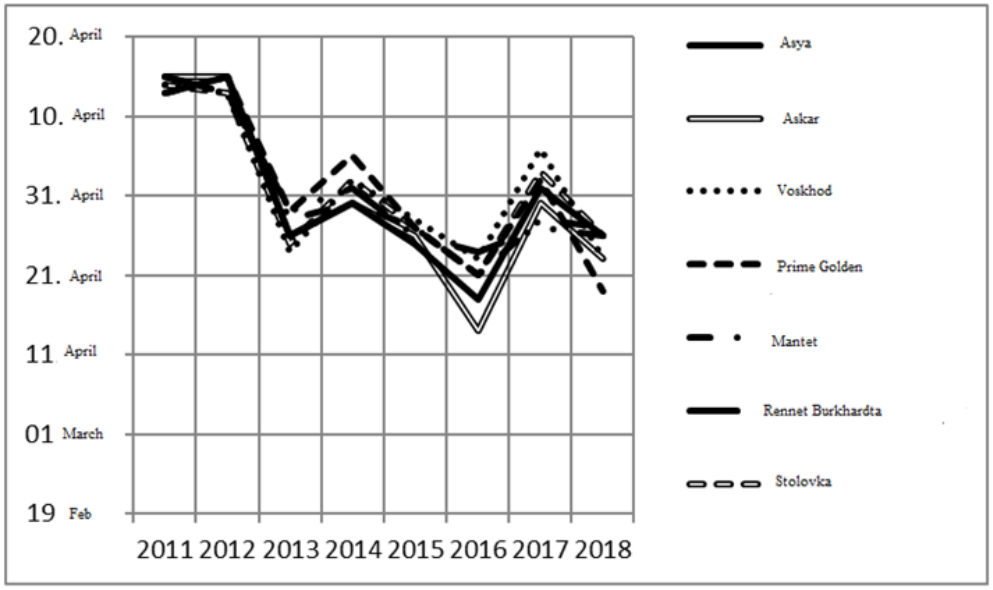

Fig. 2. Minimum decadal air temperatures in 2011 - 2018

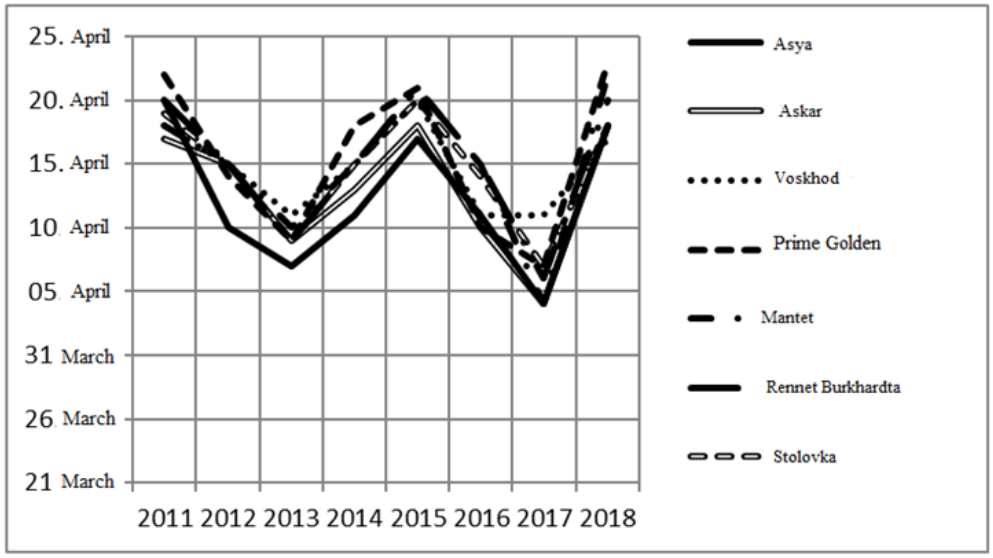

Fig. 3. Minimum decadal air temperatures in 2011 - 2018

on average. Zailiyskoye, Voskhod and Asya varieties had shorter lignification period (30.1 ± 8.7 - 35.3 ± 3.9), and for Saltanat variety lignification period lasted during 55.4 ± 10.4 days. The feature of our conditions was that the lignification took place in extremely high temperatures during July-August (up to 38 °C). In September - early October, when the air temperature dropped to a comfortable 20 - 26 °C, an abundant watering could provoke secondary (autumn) growth of shoots. The fall of leaves in all varieties was observed during the second decade of November (16 - 19. 11), the growing season made 230 - 234 days on the average.

Under extreme conditions of Mangistau, as we noted earlier (Kosareva and Dinova 2016, Kosareva et al. 2018), the differences in phenodate duration between different varieties are less pronounced during each particular year than in the same variety during different years of observation (**Figs. 2** and **3**).

The analysis of phenodate variation coefficients and the periods of growth and development, presented in **Tables 2**–**3**, makes it possible to estimate the variability of phenophase periods and duration for individual varieties and to reveal more stable ones among them.

Phenodate variation coefficients comparison (**Table 2**) showed that spring phenophases of vegetative organs (bud opening, the separation of leaves, shoot growth beginning and end) have a significantly higher variation coefficient in all varieties than the spring phenophases of generative organs (the opening of flower buds, budding, the beginning and the end of flowering).

Table 2. Phenodate variation coefficient among apple varieties

Variety name	Vegetative organs						
	Bud opening	Leaf separation	Shoot growth		Lignification		Leaf fall
			beginning	end	beginning	end	
Askar	16.5	10.4	5.4	8.4	10.7	2.3	1.7
Asya	15.9	9.2	6.1	7.8	11.5	4.7	1.7
Voskhod	19.4	8.5	6.4	8.0	9.5	3.9	1.9
Zailiyskoye	14.7	9.4	5.9	8.7	10.9	1.5	1.6
Prime Golden	16.4	8.6	5.5	8.5	10.7	1.7	1.6
Kandil – Sinap	16.0	9.3	5.0	13.6	11.1	1.8	1.7
Mantet	20.5	9.3	5.9	8.8	11.5	1.1	0.7
Rennet Burkhardta	13.5	8.3	5.3	8.9	11.0	2.2	2.1
Saltanat	15.9	7.3	6.9	7.8	12.5	4.9	0.6
Stolovka	15.1	9.5	6.7	7.8	10.5	2.4	1.7
Florina	25.8	8.1	6.1	21.9	10.9	1.7	1.8

Variety name	Generative organs						
	Bud opening	Budding	Flowering		Fruit ripening		Fruit fall
			beginning	end	beginning	end	
Askar	6.2	4.6	4.8	3.6	7.7	6.6	6.8
Asya	15.5	7.3	4.5	3.2	8.5	7.2	7.8
Voskhod	15.6	3.0	4.2	4.0	5.8	5.0	5.4
Zailiyskoye	6.2	4.5	4.7	3.8	8.5	7.8	7.4
Prime Golden	7.1	5.1	5.3	3.7	5.1	3.0	3.4
Kandil – Sinap	8.3	6.7	5.3	5.6	5.3	4.4	4.3
Mantet	16.1	5.5	5.0	3.5	6.3	4.0	3.5
Rennet Burkhardta	5.6	4.8	4.5	3.3	6.4	4.3	3.7
Saltanat	5.7	5.0	4.8	3.4	8.4	6.7	6.3
Stolovka	6.1	4.2	3.7	3.2	6.3	6.3	2.6
Florina	5.5	5.5	4.9	3.8	8.3	6.1	5.7

Table 3. The coefficient of apple tree varieties growth and development period variation

Variety name	Period duration (in days)				
	Shoot growth	Flowering	Lignification	Fruit ripening	Vegetation
Askar	24.8	22.2	58.7	31.1	4.8
Asya	24.9	30.2	74.5	78.0	4.4
Voskhod	25.2	34.4	62.5	18.3	4.9
Zailiyskoye	25.2	26.6	76.1	34.0	4.4
Prime Golden	24.3	29.1	58.3	57.6	5.1
Kandil – Sinap	25.3	21.0	60.3	29.2	4.5
Mantet	24.2	28.4	59.1	40.8	3.5
Rennet Burkhardta	26.1	18.8	57.2	39.5	4.4
Saltanat	25.4	29.5	77.9	40.7	3.6
Stolovka	26.5	23.7	60.4	49.5	4.1
Florina	24.4	25.6	56.9	44.7	5.2

For example, by bud opening phase the Florin variety has the phenodate variation coefficient of vegetative bud opening 4.7 times higher than the generative ones, from 1.9 to 2.8 times higher by varieties on the average. The variation coefficient was slightly higher by the phenophases of vegetative and generative bud opening in such varieties as Asya (1.03), Voskhod (1.24) and Mantet (1.3). During the comparison of “isolation of leaves” and “budding” phase variation coefficients, the variation coefficient was 1.3 - 2.8 times higher during the vegetative phase. The variation coefficients by the phenophase “the beginning of shoot growth” and “the beginning of flowering” differed up to 1.8 times (Stolovka variety), for the phenophases “shoot growth end” and “flowering end” - from 2.0 to 5.8 times. In absolute value, the high coefficients of phenodate variation were noted in the phenophase “leaf bud opening”, “the beginning of shoot lignification”, “leaf separation”, “the end of shoot growth” and “the opening of flower buds” in some varieties (Asya, Voskhod, Mantet) (see **Table 2**). The lowest coefficient of phenodate variation is marked by the “leaf fall” phenophase.

Thus, the coefficient of phenodate variation is generally lower for generative organs than for vegetative ones, with the exception of the vegetation end phenophases (“the end of shoot lignification” and “leaf fall”).

The analysis of specific varieties revealed that the variation coefficients can vary significantly in different phenophases within the same variety. Taking into account the variability of all phenodates, Stolovka, Rennet Burkhardta, and Prime Golden variety had relatively lower variation coefficients, and Asya, Florina, Kandil-Sinap had relatively higher variation coefficients.

The variation coefficients of variety growth and development periods are presented in **Table 3**.

According to **Table 3**, the indicators of growth and development duration for apple tree varieties have significantly higher variation coefficients than the phenophases of varieties. The highest variation coefficient relates to the shoot lignification duration, as well as to fruit ripening duration, i.e. these indicators vary significantly in different years of observation. The duration of shoot growth and the duration of flowering

Table 4. The duration of growth and shoot increment value among apple tree varieties

Variety name	The beginning of growth	Growth duration (days)	X (average increment) (cm)	C_V (variation coefficient)	Growth rate (cm)	
					average	maxim.
Askar	07.05	13	5.4±0.30	17.3	0.42	0.68
Asya	07.05	20	6.9±0.80	36.4	0.35	0.86
Voskhod	06.05	21	5.4±0.30	17.3	0.26	0.60
Zailiyskoye	07.05	20	3.3±0.26	24.9	0.17	0.41
Prime Golden	10.05	9	4.2±0.64	48.0	0.47	0.84
Kandil – Sinap	11.05	20	10.5±2.55	76.9	0.53	1.16
Mantet	10.05	19	11.0±2.97	83.5	0.58	2.01
Rennet Burkhardta	11.05	9	8.2±1.66	64.0	0.91	1.64
Saltanat	11.05	9	8.6±1.99	73.2	0.96	1.94
Stolovka	07.05	11	3.8±0.40	32.9	0.35	0.48
Florina	10.05	17	10.3±1.45	44.7	0.61	1.82

also varied quite significantly over the years of observation. And only the growing season duration remained a fairly stable one throughout the observation period. In general, the varieties Askar, Mantet, Rennet Burkhardta differed by the lower variation coefficients concerning the growth and development periods of apple tree varieties, and the varieties Asiya, Saltanat, Voskhod differed by the highest variation coefficients.

In 2018, the measurements were made to determine the duration of growth and the growth value of the apical and lateral shoots in the skeletal branches of an apple tree. The results are presented in **Table 4**.

The growth of shoots began in all varieties from 06.05 to 11.05. The earliest growth was observed in Voskhod variety, then since May, 7 the growth of shoots was noted in Zailiyskoye, Askar, Asya, and Stolovka varieties. Since May 10, the growth began for Prime Golden, Mantet and Florina varieties. The most recent start of shoot growth was observed for Rennet Burkhardta, Kandil-Sinap and Saltanat variety (May 11) (see **Table 4**). The longest growth was observed for Voskhod variety (21 days), as well as for Asya, Zailisky, and Kandil-Sinap (20 days) varieties. The shortest growth period was observed for Prime Golden, Rennet Burkhardta and Saltanat varieties (9 days). The highest average growth of shoots was observed among Mantet, Kandil-Sinap and Florina varieties, the lowest one - for Zailiyskoye, Stolovka and Prime Golden varieties (see **Table 4**). Since all varieties are of the same age and were grafted on the same stock and were grown on the same agricultural background, the duration of shoot growth and the average growth also depended on variety biological characteristics.

As can be seen from **Table 4**, the duration of growth does not always correlate with the increase magnitude. For example, the variety Voskhod with the longest growth period has a rather low average growth of shoots (5.4 ± 0.30 cm). Zailiysky variety has the longest shoot growth period and it showed the lowest average growth of shoots (3.3 ± 0.26 cm). At the same time, the variety Saltanat and Rennet Burkhardta, whose shoots are the shortest ones, have a rather high growth of shoots (8.6 ± 1.99 - 8.2 ± 1.66 cm). Kandil-Sinap, Mantet and Florina varieties have a high average growth of shoots which is combined with a rather long period of shoot growth (see **Table 4**). Obviously, Saltanat and Rennet Burkhardta variety had the highest average shoot growth rate (0.96 cm and 0.91 cm), which allowed these varieties to achieve the significant growth of shoots during the shortest growth period. The maximum growth rates of these varieties are also among the highest ones (1.94 cm and 1.64 cm, respectively). The Prime Golden variety characterized by a short growth period showed a lower growth rate (0.47 cm and 0.84 cm). Thus, it had a rather low growth of shoots. Mantet, Florina and Kandil-Sinap varieties are marked by the highest rates of maximum growth rate, which allowed them, along with a long period of growth, to achieve the highest growth rate of shoots as compared with other varieties.

In 2018 the growth of shoots was significantly lower, and the growth period was shorter than in 2017 (Kosareva et al. 2018), however, such varieties as Mantet, Kandil - Sinap, Saltanat, Florina, Rennet Burkhardta were constantly characterized by a relatively higher growth rate of shoots, and Zailiyskoye and Prime Golden varieties were characterized by a lower growth rate of shoots. The exception was the variety of Stolovka, whose growth rates were among the highest ones during the previous year and among the lowest ones in 2018.

The determination of shoot growth dynamics over a number of years revealed a significant variability of the growth period and the increase value over the years of observation, presented in **Fig. 4**.

The indicators of growth duration and shoot increment value of the same variety differ significantly in different observation years, as well as the dates of the main phenophase occurrence. However, the variation coefficients of the average growth rates of shoots are much higher than those of the average apple tree phenodates and are comparable with the variation coefficients for lignification and fruit ripening period.

Low variation coefficients were noted for Askar and Voskhod variety (17.3), as well as for Zailiyskoye, Stolovka and Asya variety (24.9 - 36.4) (see **Table 4**). In general, 7 varieties (Askar, Voskhod, Zailiyskoye, Stolovka, Asya, Florina and Prime Golden) had quite low variation coefficients for average growth rates (from 17.3 to 48.0), which is significantly lower than in 2017 (from 33.6 to 74.2). The remaining 4 varieties (Rennet

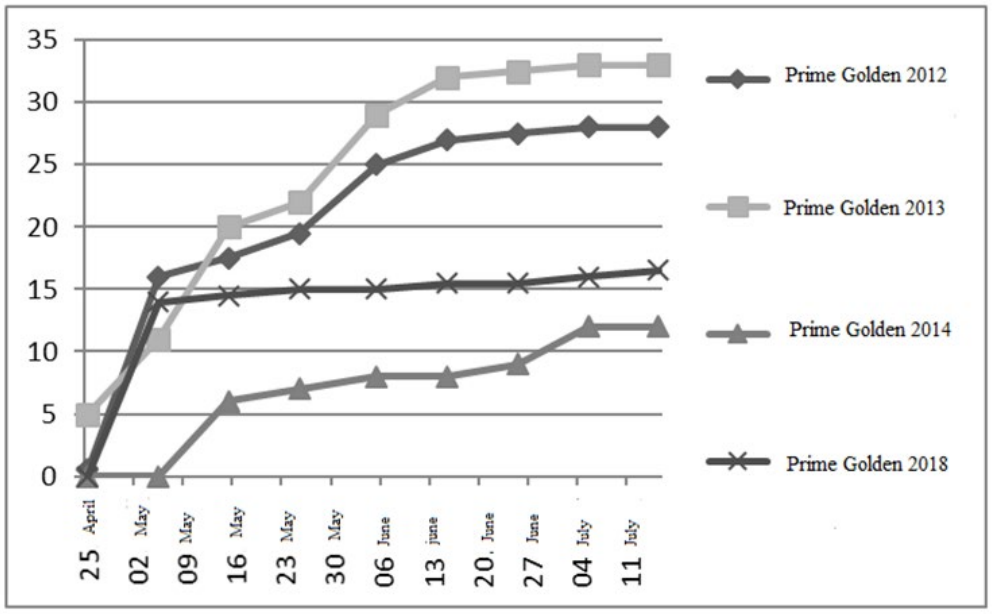

Fig. 4. Minimum decadal air temperatures in 2011 - 2018

Table 5. Yield and fruit weight of 9-year-old apple tree varieties

Variety name	Fruition age	Average yield (kg/tr.)	Fruit weight (in grams)		
			X (average)	C_v (variation coefficient)	X (maxim.)
Askar	4	9.9	141. ±11.50	32.5	246.7
Asya	3	7.7	71.1±3.94	28.4	127.4
Voskhod	4	8.1	91.2 ±10.48	62.9	338.8
Zailiyskoye	3	7.9	96.2 ± 2.55	14.5	131.1
Prime Golden	3	12.2	67.4 ±2.55	20.7	91.4
Kandil – Sinap	5	7.6	100.4 ±4.04	22.1	155.7
Mantet	3	12.8	69.1±3.07	24.3	133.6
Rennet Burkhardta	3	11.1	52.1 ±2.82	29.6	90.2
Saltanat	5	5.7	89.7 ±6.06	37.0	191.7
Stolovka	5	14.3	54.0 ±2.08	21.1	73.7
Florina	5	11.4	84.8 ±2.55	16.5	130.0

Burkhardta, Saltanat, Kandil - Sinap, Mantet) had higher variation coefficients of the average growth rates than in 2017. Very similar values of the variation coefficients for the average growth rates were observed among the Rennet Burkhardta, Prime Golden and Florina varieties.

In order to determine the prospects of apple tree varieties, along with the rhythms of growth and development, such characteristics of a fruit tree as early fruition, yield and the mass of fruits are important. (The average harvest was determined for 2016 - 2018). These data are presented in **Table 5**.

Asya, Zailiyskoye, Prime Golden, Mantet and Rennet Burchardta varieties were the early maturing in our conditions. Their first fruiting occurred at the age of 3 years. The fruition of other varieties occurred at the age of 4–5 years, i.e. also much earlier than in the descriptions of varieties. The richest harvest from one tree was obtained in 2017, the lowest one in 2018 during the three-year period. In terms of the average yield (see **Table 5**), the best is the Stolovka variety, as well as the Mantet and the Prime Golden varieties. During the most fruitful year of 2017, the best varieties were Prime Golden, Askar, Mantet, and Stolovka (Kosareva et al. 2018). Relatively low yields were constantly observed among the varieties Saltanat, Voskhod, and Zailiskoe.

According to the average fruit size, the largest ones were represented by Askar variety (see **Table 5**). The fruits of medium size were represented by Kandil-Sinap, Zailisky, Voskhod, Saltanat, and Florina varieties, below the average size - Asya, Prime Golden, Stolovka and Rennet Burkhardta variety. In most varieties, the average weight of the fruit was lower (Askar, Rennet Burkhardta, Florina) or significantly lower (Asya, Prime Golden, Saltanat and Stolovka) as compared to literature. Voskhod, Zailiyskoye, Kandil-Sinap are the varieties that retained their characteristic mass of the fruit. At the same time, some very large fruits were found in Voskhod, Askar and Saltanat varieties (up to 338.8 g for Voskhod variety). Separate large fruits were found in Kandil-Sinap, Mantet, Zailiyskoye, Florina and Asya varieties, medium-sized fruits - Prime Golden, Rennet Burhardt and Stolovka varieties. The variation coefficient for the mass of fruits was the lowest one among the varieties Zailiyskoye, Florina, Prime Golden, Stolovka and Kandil-Sinap (see **Table 5**). The highest variation coefficient of the trait was recorded for Voskhod variety.

RESULT DISCUSSION

The introduction success depends on the compatibility of introduction area environmental conditions with the range of introduced variety adaptive capabilities. Mangistau, located in the desert zone of Western Kazakhstan, has a number of specific natural conditions that distinguish it from other arid regions. The winter period is usually short, characterized by frequent thaws and unstable snow cover. The average January temperature is from -3 to -5.5 °C, but in some years it can deviate from the norm sharply (drop to -26 °C, rise to + 18 °C) (Borovsky et al. 1974). Strong winds (often above 15 - 20 m/s) and the absence of snow cover in cold winters lead to deep soil freezing. Although extremely low temperatures have not been observed in recent decades, there have been the cases of introduced species death due to renewed vegetation during the thaw and subsequent frost, or from winter dehydration resulting from intense wind conditions and dry soil. Therefore, the selection of introduced species with deep winter dormancy is important. Introduced species are subjected to severe tests during the spring-summer period, which is characterized by a large amplitude of daily air and soil temperatures (from +8 - + 10 °C at night to + 40 - + 47 °C during the day). The heating of soil reaches 60 - 70 °C, there is little or no precipitation in summer, evaporation is 10 - 13 times more than the amount of precipitation. Even with irrigation, introduced species suffer from low air humidity, which drops to 10–15% at times. The plants with low heat and drought tolerance, have the burns of leaves and young shoots, there is a summer leaf fall. The presence of a layer of shell rock, sometimes emerging on the surface, as well as soil salinity make significant difficulties for the introduction of plants. Under these conditions, intensive irrigation can lead either to secondary salinization or to the accumulation of highly saline water on the shell rock - waterlogging. The specific natural conditions leave a deep imprint on the ontogenesis process of the introduced species, and the seasonal rhythms of growth and development change.

Observations carried out for the representatives of wild fruit tree collection over a 40-year period revealed a high variation degree in the dates of phenophase occurrence by observation years among the fruit plants of different systematic and geographical origin (Imanbaeva et al. 2012, Kosareva and Dinova 2016).

The dependence of growing season beginning on the sum of effective temperatures (Abdurakhmanov and Zaitsev 1983) is also noted in the literature. The plants that are not provoked by winter and early spring thaws, i.e. with later periods of the growing season start and subsequent spring phenophases are the most prospective ones for the introduction. The low coefficient of phenodate variation for each particular phenophase indicates the relative resistance of the variety to sudden changes in weather conditions. Therefore, in our opinion, the varieties with later periods of the growing season beginning and a low coefficient of phenodate variation (Prime Golden, Kandil-Sinap) are more promising ones for local cultivation.

We have repeatedly noted a high variation degree concerning the onset of phenophases by observation years (Kosareva and Dinova 2016, Kosareva et al. 2018). When phenodate variation coefficients are compared, it was found that spring phenophases of vegetative organs (opening of buds, separation of leaves, shoot growth beginning and end) have a significantly higher variation coefficient in all varieties than spring phenophases of generative organs (the opening of flower buds, budding, flowering beginning and end) i.e. the spring phenophases of generative organs are less prone to phenodate fluctuations over observation years.

It was found that among all introduced fruit plants, most of the apple tree varieties belong to the group with the average periods of early growth and its late completion (Kosareva and Dinova 2016). Longer growth of shoots was observed among young plants. Considering that in our experience all varieties of the same age are grafted on the same stock and are grown on the same agricultural background, the length of growth and the increment of shoots depend only on the biological characteristics of varieties. As follows from our observations, the duration of growth does not always correlate with the increasing magnitude. The magnitude of growth and the growth rates of shoots are more significant indicators. In the first half of May, the most favorable conditions are usually formed for apple tree growing. Therefore, the varieties with an early onset of the growth phase of shoots and high growth rates have the advantage, which is not always combined in one variety. The highest growth rate of shoots was observed for the variety Mantet, Florina and Kandil-Sinap, which allows them, along with a long period of growth, to achieve a high value of shoot growth as compared to other varieties. The increment value could vary over the years of observation, but the leading position of such varieties as Mantet, Kandil-Sinap, Saltanat, Florina and Rennet Burkhardta remained.

In difficult conditions of the winter period, the plants with a deep winter dormancy have its advantages as was mentioned earlier. The lignification of all varieties ended in our conditions during the third decade of August, the seven-day difference by average lignification periods is not significant, as the air temperature remains high (extremely high at the end of August) for the next 30 - 40 days. A secondary shoot growth can be observed with its decrease in September to a comfortable level for varieties. Under these conditions, it is important to comply with the recommended agricultural practices, reducing irrigation rate and frequency (Kosareva 2012).

The presence of shell rock and soil salinity complicates the introduction of fruit plants. Under the conditions of the Crimea, they demonstrated a negative effect of stony-gravel and pebble soils on apple tree growth and productivity. The maximum permissible levels of the skeleton content and the depth of the dense rocks for apple trees turned out to be different depending on soil and climatic conditions, stock and variety characteristics (Opanasenko 1977). The alkalization of alkaline soils in the steppe zone of the Crimea is considered as one of irrigation adverse effects (Klimenko 1990). They showed a sharp decrease in the total mass and the length of overgrown roots during soda salinization. They marked the dependence of resistance to salinity on the biological characteristics of varieties. Under our conditions, the study of the root systems was conducted for 5 species of 1-4-year-old apple trees (Kosareva 1984). It was revealed that the bulk of the roots is located at the depth of up to 50–60 cm, in a slightly saline soil horizon. Salinity is an important factor preventing the growth of roots deep into the soil, i.e. the increase of chloride and sulfate water-soluble salts, starting from the depth of 60–80 cm. The study of various irrigation methods also revealed significant changes in the ameliorative state of soil (Dinova et al. 2017). Due to the washing irrigation regime, they observed a substantial soil washing from salts. The salt content along meter thicker decreased by 2–3 times on the average, however, the salinity chemistry changed for the worse - from sulfate-chloride to soda-sulfate. In contrast to salinity, all irrigation methods led to the deterioration of the solonetzic soil regime (Dinova et al. 2017).

Soil - climatic conditions change the processes of introduced species growth and development profoundly. We found short stature of both species and varieties of apple trees on saline soils with close bedding of shell rock (Kosareva 2002, Kosareva et al. 2018). They marked an early onset of fruiting age (early varieties), characteristic of many fruit plants under our conditions (Kosareva 2002, Kosareva and Dinova 2016, Kosareva and Lyubimov 1987).

We have repeatedly noted the early onset of fruiting age among the introduced species of apple trees, this pattern was also confirmed among varieties. During the second year after landing, i.e. at the age of three years, Asya (according to literary data, the first fruiting was observed at 9-10 years old), Prime Golden, Rennet Burhardta, Zailiyskoye (under normal conditions, fruiting occurred at the age of 5-6 years) varieties were fruited. Fruiting age decrease was found in all varieties except Florina (Kosareva et al. 2018).

The average fruit weight of introduced apple tree varieties turned out to be lower than the literature data for 8 varieties (Dzhangaliev et al. 1969), only Voskhod, Zailiyskoye and Kandil-Sinap varieties retained the characteristic size and fruit mass. Under the conditions of the Crimea, the average mass of Florina variety fruits makes 130 g (Litchenko 2008), in our conditions it makes 84.8 g, and only individual fruits reach the mass of 130 g.

The largest fruits are found in Askar variety, the fruits of average size - Kandil-Sinap, Zailiyskoye, Voskhod, Saltanat, and Florina varieties. At the same time, individual fruits of the varieties Voskhod, Askar and Saltanat had very large sizes and weights, from 191.7 g. (Saltanat) to 338.8 g. (Voskhod).

The yield of varieties in 2017 was the highest one for the period from 2016 to 2018 and is generally close to the literature data. The yield of the best in our conditions Prime Golden variety makes up to 26.2 kg per tree (Kosareva et al. 2018). However, the average yield over 3 years of observations turned out to be significantly lower - from 12 to 14 kg per tree among the best varieties (Stolovka, Mantet, and Prime Golden).

According to the combination of features (relatively high yield, low coefficient of phenodate variation, relatively late start of the growing season, etc.), Prime Golden, Stolovka and Mantet varieties are the most stable and promising ones for the crop introduction in local conditions.

The varieties with a high phenodate variation coefficient and individual valuable traits (Asya, Kandil-Sinap, Florina, and Askar) can be recommended for selection work.

CONCLUSIONS

It received statistically reliable results of long-term pheno-observations for 11 varieties of apple trees with 14 phenophases of vegetative and generative organs and 5 periods of growth and development. It determined the average phenodates of the main phenophases and the average duration of growth and development periods for apple varieties.

It has been established that the phenodate variation coefficients of generative organs are significantly lower than the coefficients of vegetative organ phenodate variation during the spring-summer period, i.e. the variability of vegetative organ phenodates is higher than the generative ones. It revealed the varieties characterized by low coefficients of phenodate variation, i.e. more resistant to local conditions: Stolovka, Rennet Burkhardta and Prime Golden.

It revealed a high variation coefficient of the growth period and shoot increment value. It was noted that the duration of growth did not always correlate with the magnitude of shoot growth. To a large extent, the magnitude of growth depended on the hereditarily determined growth rate of a particular variety of shoots.

The duration of shoot lignification and fruit ripening periods was characterized by the highest variability during the years of observation. Fruit ripening as a whole

shifted to earlier periods, however, the sequence (from summer to autumn varieties) was not disturbed.

Introduced varieties showed an early age of the first fruiting (3–5 years), the decrease of the average yield and the average mass of fruits. At the same time, they marked the presence of some very large fruits in some varieties (Voskhod), i.e. a high variability of fruit mass.

A relatively high stable yield was observed among the varieties Stolovka, Mantet, and Prime Golden, while the average fruit weight decreased.

The varieties Zailiyskoye, Florina, Prime Golden, Stolovka, Kandil-Sinap also had a low variation coefficient of fruit mass.

According to the combination of features (relatively high yield, low coefficient of phenodate variation, relatively late start of the growing season, etc.), the most stable and promising varieties for the introduction into the crop in local conditions are the following ones: Prime Golden, Stolovka and Mantet.

The varieties with a high phenodate variation coefficient and individual valuable traits (Asya, Kandil-Sinap, Florina, and Askar) can be recommended for selection work.

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