

Expression of adaptation potential by cultivars of highbush blueberry when introduced to Belarusian Polesia

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Abstract. Highbush blueberry is a group of endemic species from North America. Its introduction to Belarusian Polesia is associated with transfer of cultivars of this group into an environment with a harsher climate. Adaptive capacity of highbush blueberry allowed its cultivars to adapt to the new environment, fully develop their fruits and complete their vegetation cycle. The property of the plants to fully utilize the time of their vegetation period manifested as shortening of the completion of the main phenophases due to the influence of the temperature factor. In an introduced environment the speed of the phenophases significantly depended on the peak day temperatures, which allowed the cultivars to successfully develop their fruits in an environment where they don't receive sufficient heat during the vegetation period, as well as to complete the vegetation cycle.

1 Introduction

There are no two places on Earth with identical climate, soil and other conditions. As such, any plant upon introduction finds itself in a new for it environmental conditions. By reacting to these conditions, the plant begins to adapt to them and change itself within its reaction norm. Adaptive capacity of the introduced plants is cumulative manifestation of their adaptive reaction to the limiting factors of the point of introduction.

Highbush blueberry is a group of endemic species growing along the Atlantic Coast in North America. Cultivars produced from North American blueberries were initially adapted to climate factors of that region. When introduced in Belarusian Polesia the cultivar is forced to adapt to the changes in environmental factors [1].

The goal of this research was assessment of the adaptive capacity of cultivars of highbush blueberry of different ripening periods in different environmental conditions when introduced to Belarusian Polesia.

2 Materials and methods

Three cultivars with different ripening periods were selected as the object of the research: early ripening Duke, mid-ripening Bluecrop and late ripening Elizabeth. Observations were

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conducted in Gantsevichi district, Brest region on a collection field of highbush blueberry of the industrial laboratory for introduction and technology of non-traditional berry plants of the Central Botanical Garden NAS of Belarus over the course of 9 years: from 2011 to 2019. The experiments were set up according to the methodology of Dospekhov B.A.[2].

As biological rhythms, specifically the change in speed and nature of the biological processes over time, are the most important form of adaptation of an organism to its environment, phenological rhythms of the researched cultivars were monitored. Phenological monitoring was conducted according to the methodology of I.D. Yurkevich et al. [3]. Calendar dates of occurrence of the main phenological phases and speed of their completion depending on the heat sum and fluctuations of the temperature factors during a given period were recorded. Observation data of the Gantsevichi weather station was used to calculate the heat sums, as well as to study the dynamics of the average, maximum and minimum daily temperatures, and their daily changes.

A similarly important criterion is the ability of a plant to fully develop its fruit in new climate conditions. Study of the fruiting peculiarities was conducted using the methodology of S.Ye. Korovin et al. [4]. The harvest was measured utilizing the weight method over multiple stages, as the fruits ripened, by weighing them and adding up the mass of the harvested fruits from each of the monitored plants, after which average indices were calculated for each cultivar.

Data processing was done using a personal computer with the help of Analysis ToolPak in Microsoft Excel application at a 95% level of significance.

3 Results and discussion

Highbush blueberry occurs in North America along the Atlantic Coast from 29° N to 44° N. In order to successfully finish fruiting, species of this group require no less than 150 days with temperature above +10°C. The vegetation period in the growing area of this group blueberry plants lasts from 155 to 235 days, the number of days with temperature above 0° C varies from 240 to 270 and more, absolute minimum winter temperatures in only two states (Maine and Ontario) rarely reach -30° C, and most often do not below the -20° C mark. Sum of active temperatures varies from 2500° C to 3900° C and more, thermal time – from 3000° C to 4400° C.

Gntsevichi district is situated in southwest Belarus, roughly at latitude 52° N, which is approximately 900 km further north than the northernmost place where blueberry occurs in North America. In addition, the area of introduction is situated deep within the continent and is characterized by a temperate continental climate, unlike the humid continental climate of North America in the growing area of highbush blueberry. Main climate characteristics: length of the vegetation period, number of days with temperature below 0°, thermal time and sum of active temperatures during the monitoring period varied within the ranges comparable to similar indices in USA, although they were somewhat lower (table 1).

One of the mechanisms of the expression of the adaptation potential is the ability of a plant to make full use of the time during the vegetation period. As a rule, biological rhythms coincide in their periodicity with regular changes in ecological factors, such as temperature, duration of the daylight hours, etc. As a result of the monitoring, a significant variation in the calendar dates of beginning and duration of the phenological phases depending on meteorological conditions of the observation year (table 2,3) as well as on cultivar properties has been established.

In particular, mass flowering during the monitoring period was observed for the early ripening cultivar Duke during the period between April 30 and May 29 and with thermal time ranging from 350°Cd to 660°Cd, for the mid-ripening cultivar Bluecrop – in the

period between May 2 and May 23 and with thermal time from 370°Cd to 650°Cd, and for the late ripening cultivar Elizabeth – from May 8 to May 26 and with thermal time from 470°Cd to 690°Cd. The length of the flowering phenophase itself was 19 to 47 days for Duke, 16 to 48 days for Bluecrop and 23 to 48 days for Elizabeth.

Table 1. Climate situation of the Gantsevichi district during the research period

Climate data by year	2011	2012	2013	2014	2015	2016	2017	2018	2019
Days with temp. above 0°	232	230	238	236	268	248	267	224	254
Heat sum	3115	3267	3180	3360	3260	3150	3105	3465	3405
Sum of active temp. (above 10°C)	2720	2975	2660	2690	2690	2650	2380	3080	2995
Duration of the vegetation period, days	163	186	159	140	160	159	140	175	189

Table 2. Calendar dates of the beginning of the generative phenophases during the monitoring period

Calendar dates of the generative phenophases by the observation year									
Pheno-phase	Mass flowering			Mass blooming			Mass fruiting		
	Cultivar	Duke	Blue-crop	Elizabeth	Duke	Blue-crop	Elizabeth	Duke	Blue-crop
2011	29.05	23.05	26.05	30.05	29.05	31.05	25.07	25.07	23.08
2012	12.05	12.05	16.05	16.05	15.05	24.05	15.07	10.08	25.08
2013	17.05	19.05	19.05	21.05	23.05	24.05	15.07	1.08	30.08
2014	4.05	3.05	13.05	14.05	20.05	20.05	16.07	20.07	20.08
2015	23.05	23.05	26.05	25.05	30.05	28.05	4.08	15.08	1.09
2016	11.05	17.05	24.05	20.05	20.05	30.05	15.07	25.07	5.09
2017	19.05	19.05	21.05	26.05	26.05	31.05	7.08	17.08	15.09
2018	30.04	2.05	8.05	8.05	11.05	15.05	20.07	27.07	14.08
2019	8.05	20.05	21.05	17.05	24.05	25.05	25.07	10.08	2.09

Table 3. Heat sum during the vegetation period before the beginning of the generative phenophases during the monitoring period

Heat sum during the generative phenophases by the observation year									
Pheno-phase	Mass flowering			Mass blooming			Mass fruiting		
	Cultivar	Duke	Blue-crop	Elizabeth	Duke	Blue-crop	Elizabeth	Duke	Blue-crop
2011	660°	560°	615°	680°	660°	700°	1750°	1750°	2280°
2012	455°	455°	500°	500°	490°	630°	1380°	1730°	1970°
2013	470°	510°	510°	550°	585°	600°	1525°	1830°	2380°
2014	485°	475°	590°	600°	595°	595°	1680°	1760°	2420°
2015	650°	650°	690°	675°	750°	730°	1910°	2170°	2470°
2016	500°	590°	670°	610°	610°	770°	1630°	1800°	2040°
2017	560°	560°	575°	660°	660°	745°	1940°	2130°	2590°
2018	350°	370°	470°	470°	525°	580°	1235°	1390°	1800°
2019	420°	570°	590°	515°	640°	660°	1960°	2240°	2680°

A similar situation was observed during the blooming phase. For example, mass blooming during the monitoring period was noted for the Duke cultivar from May 8 to May 30 with thermal time from 470°Cd to 680°Cd, for Bluecrop – from May 11 to May 30 with

thermal time from 490°Cd to 750°Cd, for Elizabeth – from May 15 to May 31 with thermal time from 580°Cd to 770°Cd. The length of the blooming phenophase varied from 19 to 30 days for Duke, from 17 to 30 days for Bluecrop, from 16 to 25 days for Elizabeth.

Even more significant divergence was observed in the fruiting period. Mass fruiting depending on the monitoring year was noted for the Duke cultivar in the interval from July 15 to August 7 with heat sum from 1235° C to 1960° C, for the Bluecrop cultivar – from July 20 to August 17 with heat sum from 1390° C to 2240° C, for the Elizabeth cultivar – from August 14 to September 15 with heat sum from 1800° C to 2680° C. The duration of this phenological phase also varied considerably with observation years, and was 29-54 days for Duke, 36-63 days for Bluecrop, 47-83 days for Elizabeth (tables 2, 3, 4)

Table 4. Lengths of the phenophases in the monitored cultivars of highbush blueberry

Observation year	Lengths of phenophases (days) in cultivars of highbush blueberry								
	Flowering			Blooming			Fruiting		
	Duke	Blue-crop	Eliza-beth	Duke	Blue-crop	Eliza-beth	Duke	Blue-crop	Eliza-beth
2011	19	16	23	19	17	24	39	36	56
2012	30	28	26	25	24	21	54	63	83
2013	25	26	28	21	19	20	48	53	80
2014	35	33	30	27	25	17	34	63	38
2015	37	47	39	30	30	24	36	40	67
2016	47	48	48	21	18	16	35	48	53
2017	27	31	31	22	22	25	29	50	59
2018	26	25	29	21	20	19	30	42	47
2019	37	25	27	29	20	25	42	63	73

As can be seen from the data provided, occurrence of main phenophases in cultivars of highbush blueberry varies within a wide range of calendar dates and thermal times. The lengths of these phenophases also varies considerably. At the same time, if the data in tables 3 and 5 is to be analyzed, dependence of time of the beginning and speed of the completion of generative phenophases in blueberry cultivars on the number of warm days during that phenophase becomes apparent.

Table 5. Number of days with maximum temperature above +20°C by 10 day intervals

Observation year	Number of days with maximum temperature above +20°C																	
	May			June			July			August			September			October		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
2011	2	7	9	10	8	8	6	8	10	10	10	9	6	7	5	2	-	-
2012	6	5	9	4	8	8	10	8	11	9	7	9	6	5	2	2	-	-
2013	5	10	8	10	9	10	10	8	7	10	10	6	3	2	-	-	-	-
2014	4	4	8	9	5	4	10	9	11	10	10	5	5	6	-	2	3	-
2015	2	2	6	10	10	7	10	9	11	10	10	11	4	6	4	2	-	-
2016	7	3	11	8	8	10	10	10	10	10	7	11	10	6	1	1	-	-
2017	3	3	10	7	8	9	7	10	11	10	10	6	4	4	1	-	1	-
2018	9	7	10	9	10	7	6	10	11	10	10	10	10	8	1	1	3	-
2019	-	7	10	10	10	10	5	7	11	9	10	11	10	3	-	1	5	2

For example, in 2016 and 2017, at times of the longest duration of the flowering paze, the number of days with daytime temperature above 20° C was 3-7 in the 1st 10 day period of May, 3 in the 2nd, and only reached 10 days in the 3rd. A similar situation was observed in 2015, when the number of days with temperature above 20° C by 10 day periods in May was 2, 2 and 6 days, and in 2012, with the number of warm days by 10 day periods in May being 6, 5 and 9, respectively. A similar situation could be observed during the blooming

and fruiting phenophases. The more days with temperatures above 20° C those periods had, the faster the observed phenological phase was completed. And, conversely, with increased number of days with air temperature during daytime below 20° C the length of the phenological phases increased (table 4, 5).

Similarly, temperature indices of the vegetation period affected the crop yield of cultivated blueberry, analysis of which has been prior [2, 3]. The more days with temperatures above 20° C there was during the periods of fruiting and initiation of flower buds, the faster the fruiting phase was completed and the more flower buds were initiated during that period, which positively affected the volume of the harvest in the following year. Crop yield of early ripening, mid-ripening and late ripening cultivars all depended on this variable. Late ripening cultivars receive roughly half as many days with temperatures above +20° C for the flower bud initiation period than mid-ripening ones. And, accordingly, crop yield of late ripening cultivars was annually twice lower than for early and mid-ripening ones.

4 Conclusion

- cumulative manifestation of the adaptive reaction of highbush blueberry to limiting factors of the place of introduction is varying dates of the beginning and the speeds of the phenological phases, as well as significant differences in crop yield by year;
- lengths of individual phenophases in cultivars of highbush blueberry during the vegetation period are regulated by a whole range of climate factors, the most evident of which is the influence of the temperature factor;
- speeds of the phenophases significantly depend on maximum daily temperatures, which helps explain cultivars of highbush blueberry successfully developing their fruit in an environment with insufficient heat sum during the vegetation period;
- the influence of the temperature factor on the speed of phenophase completion and crop yield can be clearly observed, despite the genetically determined cultivar specifics of highbush blueberry.

References

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