PRELIMINARY OBSERVATIONS OF PHENOLOGY DEVELOPMENT, YIELD AND YIELD QUALITY OF SOME HIGHBUSH BLUEBERRY CULTIVARS IN LATVIA

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Abstract. Cultivars of northern highbush blueberries (*Vaccinium corymbosum* L.) are the most suitable for areas with long, cold winter, because they require the greatest number of winter chilling hours. The blueberries are excellent sources of phytochemicals that are believed to have a significant biological activity. The experiment was done at the Institute of Agrobiotechnology, Latvia University of Agriculture, Jelgava, in the year 2009. The aim of the experiment was to evaluate phenological development of 9 highbush blueberry cultivars, their yield, fruit weight and biochemical composition: total anthocyanins, total phenols, ascorbic acid, titratable acids, and soluble solids. The obtained data showed correlation between duration of flowering and fruit ripening; between harvest and end of vegetation period of the highbush blueberry. The phenological development was dependent not only on cultivars, but also on the effective air temperature (above + 5 ºC). The research results allow to assess the phenology development of blueberry cultivars and predict the fruit ripening time in conditions of Latvia. The most productive cultivars were 'Patriot' and 'Northland' The biggest single berry weight presented the cultivars 'Chippewa' and 'Bluejay'. The cultivar 'Jersey' had the highest content of titrable acid, anthocyanins, and ascorbic acid. The highest phenol content was detected in highbush blueberry cultivars 'Spartan' and 'Bluecrop'.
Key words: *Vaccinium corymbosum* L., vegetation period, flowering and fruit ripening time, biochemical composition.

Introduction

Highbush blueberries (*Vaccinium corymbosum* L.) are native to North America (latitudes 40 to 45º N), Latvia is located in latitudes 55 to 58 º N, but with similar climate conditions. Highbush blueberries are an upright, 2 m high, crown-forming bush. Fruits, ranging from 3 – 20 mm in diameter, are blue-black berries with many seeds. More than 50 cultivars of highbush blueberry have been developed in North America, primarily based on selections for commercially valuable fruit characteristics and seasonality. The blueberry cultivars require from 120 to 160 growing degree days to ripen fruit.

Northern highbush blueberries require a great number of winter chilling hours and therefore are most suitable for areas with long, cold winters. The northern blueberries have a long period of apparent dormancy during winter; they need an average of 750 hours of temperature below 7 ºC before growth can begin. In general, the more chilling hours, the better, and temperatures that range from 2 to 9 ºC are most effective in promoting good and strong growth of a plant and which will give abundant fruit in the future. (Gough, 1994; Trehane, 2004). If the chilling received during the winter is not sufficient to break dormancy then growth cannot be resumed (Wang and Buta, 1997).

Blueberries is an excellent source of phytochemicals substance that is believed to have significant biological activity in the human body (Schmidt et al., 2005).

In the literature (Gough, 1994; Trehane, 2004) it has been described that the temperature at which blueberry buds are injured depends primarily on their development stage, but does not mention the length of stage of development to blueberry cultivars.

The aim of this experiment was to compare the phenological development, including flowering and fruit ripening length and times, and yield quality of some highbush blueberry cultivars in conditions of Latvia.

Materials and Methods

The experiment was done at the Institute of Agrobiotechnology of the Latvia University of Agriculture (LLU), Jelgava. Plants were observed during the year 2009. Seven-year-old plants highbush blueberry cultivars 'Spartan, 'Patriot', 'Chippewa', 'Northland', 'Blueray', 'Bluecrop', 'Jersey', 'Bluejay', and 'Barkeley' were evaluated in a study site. The cultivars were grouped by vegetation period: early season 'Spartan' and 'Patriot'; early midseason 'Northland' and 'Bluejay'; midseason 'Chippewa', 'Berkeley', 'Bluecrop', and 'Blueray'; late midseason 'Jersey' (Hancock and Hanson, 2001).

The trial was carried out an experimental plot on sandy soil, the plants were planted in the furrow that filled with peat (the peat pH were 4.5). Planting distance was 3 × 1 m. 17 complex fertilizer was given: 20 g m^{-2} ($N:P_2O_5:K_2O$ 8:7:21, with microelements Mg 1.6%, S 15.9%, B 0.03%, Cu 0.01%, Fe 0.2%, Mn 0.2%, Mo 0.002%, Zn 0.01%). Fertilizer was given 2 times per season: the first time at the beginning of vegetation, the second time at the end of flowering. In spring, peat was used as mulch (a 5-cm layer). No regular irrigation system was used in the trial.

The phenological development of highbush blueberry, which was defined using blueberry growth stages by Mark Longstroth from Michigan State University (Longstroth, 2008): start of vegetation (leaf development), flower-bud break, beginning of fruit growth (first fruits visible at raceme base), and harvest time (blueberries are picked several times as the fruit ripens). The highbush blueberry fruits were collected gradually, so the total yield was picked at

three to five times from the end of July 2009 to the end of August 2009.

The sum of the effective air temperature was determined using data of the Latvian Environment, geology and meteorology agency. The sum of the effective air temperature is the average daily air temperature in Celsium degrees above + 5 °C, which is the average temperature of the start of vegetative growth.

In general, the year 2009 in Latvia can be described as warm and wet enough. The average annual air temperature was + 6.5 °C (0.7 °C above the average of long term), annual rainfall - 753 mm (114% of the long term average). Winter 2008/2009 was characterized by the stability of warmth and moisture. The year 2009 was dryer than the long term average. In Jelgava, the lowest temperature was observed June 18 (- 0.2 ºC). The 1st decade of August was the driest time of the summer of 2009, when total rainfall was only 5% of the average, and precipitation made 127% of the long term average. Later the air temperature fluctuated around the long term average, and frost was not observed until early October.

The following yield and yield quality parameters were determined: yield (kg per bush), single fruit weight (g) and biochemical composition: total anthocyanins (mg 100^{-1}), total phenol (mg 100^{-1}), ascorbic acid (mg 100^{-1}), titratable acid (%), and soluble solids (%). The samples of berries were analyzed after freezing and frozen storage. The chemical composition analyses were carried out at the Latvia State Institute of Fruit-Growing. Total anthocyanins were determined by spectrophotometric method at a wavelength of 535 nm. Total phenol content was determined by spectrophotometric method at a wavelength of 765 nm. The content of ascorbic acid was determined with iodine method. Total titrable acids were determined by titration (LVS EN 12147:2001A). The content of soluble solids was determined by refractometer (LVS EN 12143:2001A).

All measurements were made in three replications. The data were statistically processed using analysis of variance (ANOVA), and standard error. Correlation coefficients were also calculated.

Results and Discussion

They year 2009 in Latvia generally was warm and wet enough. The vegetation period of most of the highbush blueberry cultivars started when the average air temperature was above +5 °C and the sum of effective air temperature was 26 °C (Table 1). The difference in the vegetation period between the earliest and latest cultivars was 17 days. The first cultivar was ‘Spartan’ (for this cultivar, the vegetation period started on 2nd April, when average air temperature in last five days was 3 °C). Beginning of flowering started at the end of the second decade of April, when the sum of effective air temperature was 145 °C. The sum of positive temperature of the flowering period was 559 °C.

Table 1

The average air temperature and the sum of effective temperature between phenological phase changes of the highbush blueberry, 2009

Phenological phase	Average air temperature, °C	Sum of effective air temperature, °C
Bud break (beginning of vegetation period)	7.3	26
Beginning of vegetation period – beginning of flowering	7.8	145
Beginning of flowering – beginning of fruit ripening	11.5	559
Beginning of fruit ripening - full ripeness	15.0	965
Full ripeness - end of vegetation period	11.2	101
Length of vegetation period	12.3	1606

The results obtained in the field trials indicate that the length of the vegetation period of highbush blueberry varied from 167 to 181 days (Table 2). In assessing the development of phenological phases there were significant differences observed between highbush blueberry cultivars ($F_{crit.}$=2.24>F_{fakt}=0.19).

The beginning of flowering is a very important parameter because of the possible damage to flowers by late spring frost. Beginning of flowering was evaluated on April 19 for cultivars ‘Spartan’, ‘Chippewa’, ‘Patriot’, ‘Northland’, ‘Blueray’ and ‘Bluejay’, and on May 3 for cultivars ‘Jersey’ and ‘Berkeley’. Difference between beginning of the vegetation period and start of the flowering was from 17 to 31 days. The best incomes are usually obtained for fruit ripening very early or very late in season. It is difficult to secure high fruit quality in cultivars ripening at either extremes because vigor is often low or modest in the earliest cultivars, and both early and late cultivars ripen under more variable environmental conditions than midseason cultivars. In the first stage of floral development, frost tolerance is critical even in areas that do not have severe winter temperatures (Galletta and Ballington, 1996).

Beginning of fruit ripening started on the 41st day (Table 2) after beginning of flowering for cultivars ‘Spartan’, ‘Patriot’, ‘Chippewa’, and ‘Bluecrop’, and on the 51st day for cultivars ‘Blueray’ and ’Bluejay’. The time of fruit ripening fluctuated from 56 to 66 days (the longest fruit ripening period was observed for cultivar ‘Bluecrop’ – 66 days).

Table 2

Days between the phenological phases of highbush blueberry cultivars

Cultivars	Beginning of vegetation period – beginning of flowering	Beginning of flowering - beginning of fruit ripening	Beginning of fruit ripening - full ripeness	Full ripeness - end of vegetation period	Full vegetation period
Spartan	17	41	64	59	181
Patriot	17	41	64	64	175
Northland	17	46	59	59	170
Bluejay	17	51	61	57	176
Chippewa	17	41	64	64	175
Blueray	17	51	61	55	173
Bluecrop	22	41	66	55	167
Barkeley	31	42	60	53	169
Jersey	31	42	56	55	167
$LSD_{0.05}$	9.2	6.7	5.3	6.4	7.3
S %	29	10	5	7	3

The coefficient of linear correlation (Table 3) demonstrates that there is a significant, negative correlation (r = -0.64) between duration of the flowering and fruit ripening of the highbush blueberry. In other researcher it has been observed that flowering time significantly correlates with harvest time in highbush blueberries (Galletta and Ballington, 1996). Gough (1994) was noted that there is neither correlation between the time a flower opens and the ripening of its fruit, nor any pattern of berry ripening within a cluster.

The yield of observed cultivars ranged from 5.99 to 0.106 kg per bush (Table 4). The most productive cultivars were 'Patriot' (5.99 kg per bush) and 'Northland' (5.26 kg), but an insignificant yield was to 'Barkeley' (only 106 g per bush), which was the reason for the small amount of racemes in the bush. The cultivars 'Chippewa' (1.8 g) and 'Bluejay' (1.6 g) gave the largest average single berry weight whereas 'Berkeley', 'Jersey' and 'Northland' presented 1.1 g of single berry weight. In natural *Vaccinium* populations, fruit size and flavour vary independently. Traditionally, large fruit has been more appealing to the producer and consumer, and is much easer to harvest and handle than small fruit, where hand labor is involved. Large fruit bring a premium on the market, and fruit size is

Table 3

Correlation between the lengths of different phenological phases

Indices	Beginning of vegetation period – beginning of flowering				
Beginning of flowering - beginning of fruit ripening	-0.34	Beginning of flowering - beginning of fruit ripening			
Beginning of fruit ripening - full ripeness	-0.53	-0.32	Beginning of fruit ripening - full ripeness		
Full ripeness - end of vegetation period	**-0.64**	-0.29	0.43	Full ripeness - end of vegetation period	
Full vegetation period	-0.68	0.11	0.42	0.55	Full vegetation period

*Underlined values significant at p=0.05

Table 4

Average yield and berry weight of highbush blueberry cultivars

Cultivars		Yield, kg per bush	Single fruit, g
Early season	Spartan	4.31	1.30
	Patriot	**5.99**	**1.55**
Early midseason	Chippewa	4.12	**1.79**
	Northland	**5.26**	1.08
Midseason	Blueray	0.76	1.30
	Bluecrop	3.47	1.31
	Jersey	0.93	1.12
	Bluejay	2.04	1.55
Late midseason	Barkeley	0.11	1.06
	p-value	0.04	

the principal grading criterion in marketing highbush fruit (Galletta and Ballington, 1996; Giongo et al., 2006). Compared with information in the literature, the single berry weight of highbush blueberry in Latvian conditions is lower. For example, the single berry weight of cultivar 'Spartan' are 2 g, 'Jersey' 1.7 g and 'Blueray' 2.2 g (Giongo et al., 2006). Berry size, however, is affected somewhat by the location of the fruit on the bush (Gough, 1994).

The content of titrable acid in berries of highbush blueberry cultivars differed between 0.58% in 'Northland' and 1.09% in 'Bluejay' (Table 5). These results are lower than in other blueberry cultivars, for example, the titrable acid content in cultivar 'Chandler' was 1.35% in 2008 (Kampuse et al., 2009). It is important for processing to find blueberry cultivars with the highest acidity therefore the cultivars 'Chandler' could be more suitable for the production of juice and other preserves (Kampuse et al., 2009). The titrable acids content in most of the cultivars did not exceed 1% and is low compared to other berry species.

The soluble solids content in the cultivars differed between 8.53% ('Barkeley') and 12.54% ('Jersey', 'Spartan', and 'Bluecrop') (Table 5). The soluble solids content in some blueberry cultivars grown in Latvia is lower than in other growing regions due to more rainy and colder climate. For example the soluble solids content in berries of cultivar 'Berkeley' was on average only 8.53%, which is notably lower compared to the data mentioned in the literature (Saftner et al., 2008). Prior et al. (1998) have indicated that soluble solids content in lowbush blueberries is 14.3%; they found much wider scope of soluble solids content in particular cultivars of highbush blueberry: 10 – 19%.

The total phenol of highbush blueberry cultivars varied from 76.80 to 118.73 mg 100 g^{-1}. The cultivars with the highest phenol content were 'Northland' and

Table 5

Average yield, berry weight, and biochemical content of highbush blueberry cultivars

Cultivars		Total phenol, mg 100 g^{-1}	Total antocyanin, mg 100 g^{-1}	Ascorbic acid, mg 100g^{-1}	Titrable acid, %	Soluble solids, %
Early season	Spartan	108.95 ±0.20	**381.14** ± 6.22	7.81 ± 0.73	0.82 ± 0.00	**12.53** ± 0.01
	Patriot	97.65 ± 4.84	234.78 ± 11.99	**11.83** ± 0.37	0.77 ± 0.00	10.74 ± 0.12
Early midseason	Chippewa	76.80 ± 4.36	230.75 ± 7.93	8.25 ± 0.16	0.59 ± 0.00	11.05 ± 0.05
	Northland	**118.73** ± 7.35	272.96 ± 10.37	7.36 ± 0.46	0.58 ± 0.00	9.56 ± 0.08
Midseason	Blueray	111.24 ± 3.93	337.92 ± 5.73	9.17 ± 0.28	0.91 ± 0.03	10.85 ± 0.05
	Bluecrop	91.72 ± 1.27	**362.17** ± 9.76	8.15 ± 0.31	0.87 ± 0.06	12.48 ± 0.13
	Jersey	**113.76** ± 5.70	261.73 ± 5.74	**10.78** ± 0.74	**0.97** ± 0.09	**12.54** ± 0.05
	Bluejay	87.40 ± 1.95	220.09 ± 9.6	7.01± 0.80	**1.09** ± 0.03	11.91 ± 0.08
Late midseason	Barkeley	99.03 ± 2.14	244.58 ± 3.21	8.13 ± 1.44	0.62 ± 0.03	8.53 ± 0.05

'Jersey' (on average 118.73 and 113.76 mg 100 g^{-1}, respectively).

The total antocyanin content of highbush blueberries differed from 226 to 381 mg 100 g^{-1}. The highest antocyanin content was detected in highbush blueberry cultivars 'Spartan' and 'Bluecrop' (on average 381.14 and 362.17 mg 100 g^{-1}, respectively).

The ascorbic acid content in highbush blueberries differed from 7.01 to 11.83 mg 100 g^{-1}. The highest content of ascorbic acid was in cultivars 'Patriot' and 'Jersey' (on average 11.83 and 10.78 mg 100 g^{-1}, respectively). It should be noted that the ascorbic acid content in highbush blueberry cultivars is low compare to other berry cultivars (currants, strawberries, etc.) (Kampuse et al., 2009)

Conclusions

1. In 2009, the vegetation period of blueberry cultivars began on the 2nd April and was from 167 to 181 days. Flowering time was from 31 to 46 days from the beginning of yhe vegetation period. The time of fruit ripening fluctuated from 56 to 66 days.
2. The most productive cultivars were 'Patriot' (5.99 kg per bush) and 'Northland' (5.26 kg). The cultivars 'Chippewa' (1.8 g) and 'Bluejay' (1.6 g) presented the biggest single berry weight.
3. The cultivar 'Jersey' had the highest titrable acid content (1.09%), the highest anthocyanins content (113.76 mg 100 g^{-1}), and the highest content of ascorbic acid (10.78 mg 100g^{-1}).
4. The highest phenol content was detected in highbush blueberry cultivars 'Spartan' and 'Bluecrop' (on average 381.14 and 362.17 mg 100 g^{-1}, respectively).

Acknowledgements

The study was supported by the Ministry of Agriculture. Academic study and publication is financed by the project "Support for doctoral studies in LUA" /Nr.2009/0180/1DP/1.1.2.1.2/IPIA/VIAA/017/ agreement Nr.04.4-08/EF2.D2.07.

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