Comunicata Scientiae
Horticultural Journal

ORIGINAL ARTICLE
published: 02 August 2021
https://doi.org/10.14295/CS.v12.3529

Production of blueberries in subtropical climate of altitude

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Abstract

Phenology and production potential studies are important to choose the cultivars more adapted to the climatic conditions of a region. The objective of this work was to evaluate the phenology, productivity and fruit quality of blueberry cultivars in subtropical climate of altitude, in three production cycles (2012/2013, 2013/2014 and 2014/2015). Eight cultivars from rabbiteye (Aliceblue, Bluebelle, Bluegem, Briteblue, Climax, Delite, Powderblue and Woodard) and two from highbush (Georgiagem and O'Neal) groups were evaluated. The experimental design was in randomized blocks with four replications and six plants per plot, with four useful plants. The beginning and the end of flowering, beginning and end of harvest, production, berry weight, berry size, pH, soluble solids, titratable acidity, ratio and skin color of blueberries were evaluated. The cultivars had flowering period from July to September, and concentrated harvest in November and December. 'Bluegem' presented the highest yields in the three evaluated cycles, reaching the production of 1215 g plant^{-1} in the third cycle. This cultivar also showed low acidity and high ratio. Berry size, pH and soluble solids contents were very close with some variations among the cultivars, in the three evaluated cycles. Coloring of the fruit presented few variations over the years of assessment. The most productive blueberry cultivar is the Bluegem, followed by cultivars Climax, Delite and Powderblue, of rabbiteye group, demonstrating better adaptation in subtropical climate of altitude.

Keywords: Phenology, Postharvest, Small fruits, *Vaccinium* spp.

Introduction

Fruit species originated from North America, the blueberry (*Vaccinium* spp.) is much appreciated for its exotic taste and nutraceutical properties (Fachinello et al., 2011). In Brazil, the blueberry was introduced in 1980 in Rio Grande do Sul, but its commercial cultivation began only after 2000, driven by growing world demand and the attractive prices of fresh fruit on the European market (Cantuarias-Avilés et al., 2014). The growth of blueberry consumption is mainly related to its high antioxidant capacity (Rodrigues et al., 2011), by the presence of phenolic compounds, mainly anthocyanins, flavonoids and cinnamic acid derivatives (England, 2015; Kang et al., 2015; Cardeñosa et al., 2016; Li et al., 2016). Besides that, the blueberry crop is an alternative for small farmers, since it can increase the income of the properties due to its high market value (Pasa et al., 2014).

Most cultivars existing in Brazil are from the United States and belong to the rabbiteye group, which require less chilling than the cultivars of the highbush group (Cantuarias-Avilés et al., 2014). Cultivars of the rabbiteye group have presented adaptation in Brazil in places with less chilling accumulation than the traditional American regions, as in states from: Rio Grande do Sul (Antunes et al., 2008), São Paulo (Cantuarias-Avilés et al., 2014), Paraná (Medeiros et al., 2017; Medeiros et al., 2018) and Minas Gerais (Concenço et al., 2014).

Studies to evaluate cultivars productive potential are important in the characterization of the existing genetic materials, since they provide knowledge about the phenological and productive behavior in different places of cultivation, as the flushing and ripening times may vary, depending on the year and place (Nesmith, 2006).

The objective of this work was to evaluate the phenology, productivity and fruit quality of blueberry

Received: 20 July 2020
Accepted: 16 March 2021

cultivars in subtropical climate of altitude.

Material and Methods

The experiment was performed at the Experimental Station of the Instituto de Desenvolvimento Rural - IDR, located in Lapa, PR, latitude 25°47´S, longitude 49°46´W and 910 meters of altitude, the climate according to the Köppen criteria is Cfb (Humid subtropical zone, with temperate summer) (Alvares et al., 2013). The chill hours bellow 7,2 °C accumulated from April to September of 2012, 2013 and 2014 were calculated (Figure 1). The hourly temperature data were recorded by Lapa Meteorological Station of the Paraná Meteorological System (SIMEPAR) and the maximum, average and minimum temperatures were recorded (Figure 2). In the orchard was not used the dormancy-breaking chemicals.

In the first year, the soil analyses showed these chemical characteristics: pH $CaCl_2$ 5.5; Al^{+3} 0.0 $cmol_c$ dm^{-3}; $H^{+}+Al^{+3}$ 4.0 $cmol_c.dm^{-3}$; Ca^{+2} 6.7 $cmol_c$ dm^{-3}; Mg^{+2} 2.5 $cmol_c$ dm^{-3}; K^{+} 0.31 $cmol_c$ dm^{-3}; P 30.5 mg dm^{-3}; C 18.2 $g.dm^{-3}$ and base saturation 70%.

The cultivars evaluated were Aliceblue, Bluebelle, Bluegem, Briteblue, Climax, Delite, Powderblue and Woodard of the rabbiteye group and Georgiagem and O'Neal of the highbush group. The experimental design was in randomized blocks with four replications and six plants per plot, with four useful plants. Planting was carried out in September 2011 at a spacing of 3 m between rows and 0.7 m between plants, in ridges with drip irrigation system. The orchard was evaluated in three productive cycles: 2012/2013, 2013/2014 and 2014/2015.

Phenological evaluations were carried out at the beginning of flowering (more than 5% of open flowers), end of flowering (90% of open flowers), beginning and end of harvest.

Blueberries were harvested at the full ripening stage for evaluation of the yield (g $plant^{-1}$), fresh fruit mass (g), fruit size (mm), hydrogen potential (pH), soluble solids content, titratable acidity and epidermis coloring. The relationship between the soluble solids content and the titratable acidity provided the ratio. Fruits were homogenized in each treatment and selected according to health and the absence of defects and injuries for withdrawal of samples. After the selection, the sample was divided into four replicates of 36 fruits.

Fruit size was determined by the equatorial diameter measured with a digital caliper. The soluble solids content (°Brix) was measured, using a refractometer, with direct reading after addition of a juice drop of the fruits on the apparatus prism. Acidity was determined by neutralization titration of fruit juice with NaOH 0,1N until pH 8.2 and expressed as a percentage of citric acid (Instituto Adolfo Lutz, 2008).

The coloring of the fruit epidermis was determined by colorimetry, using the Cielab scale, with direct reading of the values of L* (luminosity), a* (red contribution) and b* (yellow contribution). The color tone angle hue (h*) and color saturation, chroma (C*) were calculated from the values of a* and b*, according to the equations: $h^* = \arctan(b^*/a^*)$ and $C^* = [(a^*) + (b^*)]^{1/2}$.

Data were submitted to Barttlet test to evaluate the homogeneity of variances and then to analysis of variance. The variables that were significant were grouped by the Scott-Knott cluster test. Statistical analyses were performed by Assistat™ software.

Results and Discussion

The flowering period varied between the cultivars and the years, with periods of 22 to 29 days in the 2012/2013 cycle and 28 to 35 days in the cycles 2013/2014 and 2014/2015 (Table 1). The beginning and the end of flowering were more homogeneous among the cultivars in the cycle 2013/2014, probably because in the winter of 2013 there was a greater chilling accumulation (277 hours bellow 7.2°C) than in 2012 (139 hours bellow 7.2°C) and 2014 (151 hours bellow 7.2°C) (Figure 1). For Antunes et al. (2008) changes in the flowering pattern may occur due to annual variations in accumulation of chilling. The chilling hours during the rest period are important to overcome the dormancy and the accumulation of heat hours above the base growth temperature is necessary to stimulate the sprouting of the buds after this period, and the lower base temperature may differ between the cultivars (Anzanello & Biasi, 2016).

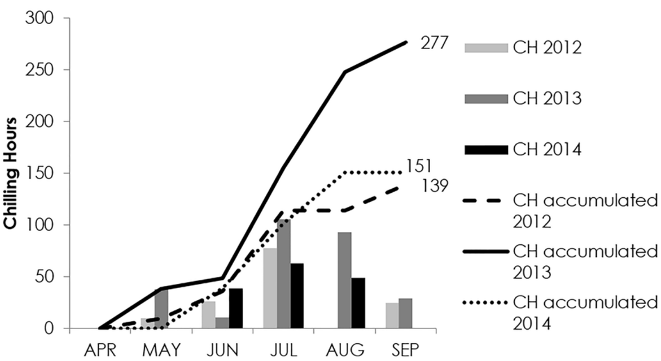

Figure 1. Chilling hours (CH) below 7.2 °C accumulated from April to September, in 2012, 2013 and 2014, Lapa, PR, Brazil. Climatic data collected in Lapa Meteorological Station of SIMEPAR.

Table 1. Flowering and harvest period of ten blueberry cultivars in the cycles 2012/2013, 2013/2014 and 2014/2015. Lapa, PR, Brazil.

Cultivar	Flowering			Harvest		
	Beginning	End	Flowering time (days)	Beginning	End	Harvest time (days)
			2012/2013			
Aliceblue	01/08	24/08	24	--	--	--
Bluebelle	27/07	17/08	22	--	--	--
Bluegem	01/08	24/08	24	07/12	20/12	14
Briteblue	01/08	24/08	24	20/12	20/12	01
Climax	20/07	17/08	29	07/12	14/12	08
Delite	17/08	06/09	21	07/12	14/12	08
Georgiagem	20/07	17/08	29	07/12	07/12	01
O'Neal	04/07	01/08	29	--	--	--
Powderblue	01/08	24/08	24	07/12	20/12	14
Woodard	01/08	24/08	24	07/12	14/12	08
			2013/2014			
Aliceblue	13/08	10/09	28	--	--	--
Bluebelle	27/08	24/09	28	12/12	19/12	07
Bluegem	27/08	01/10	35	21/11	09/01	50
Briteblue	27/08	24/09	28	12/12	09/01	29
Climax	27/08	01/10	35	05/12	02/01	29
Delite	20/08	17/09	28	--	--	--
Georgiagem	13/08	10/09	28	--	--	--
O'Neal	13/08	10/09	28	--	--	--
Powderblue	13/08	10/09	28	12/12	02/01	22
Woodard	13/08	10/09	28	05/12	02/01	29
			2014/2015			
Aliceblue	12/08	09/09	28	20/11	20/11	01
Bluebelle	22/07	19/08	28	20/11	27/11	07
Bluegem	05/08	09/09	35	20/11	06/01	47
Briteblue	15/07	19/08	35	04/11	11/12	37
Climax	05/08	09/09	35	20/11	18/12	28
Delite	12/08	16/09	35	27/11	26/12	29
Georgiagem	05/08	02/09	28	20/11	04/12	14
O'Neal	29/07	26/08	28	13/11	11/12	28
Powderblue	29/07	02/09	35	27/11	18/12	21
Woodard	29/07	02/09	35	20/11	11/12	21

In 2013 the largest chilling accumulation occurred from late July to the beginning of September, with a total chilling accumulation of the 277 hours below 7.2 °C. It is noteworthy that at the end of July 2013 there was intense cold weather (Figure 2), accompanied by temperatures below 0 °C and the occurrence of snow in Lapa, PR. This was the main cause of the delay in flowering in 2013. The flowering period of the evaluated cultivars were similar to those found by Antunes et al. (2008) in the evaluation of the phenological behavior of eight blueberry cultivars in Pelotas, RS.

Harvesting of the cultivars was variable in the evaluated cycles. In the 2012/2013 cycle the harvest was concentrated in the month of December. In the 2013/2014 cycle, only for the cultivar Bluebelle the harvest ended on December 19th and the other were harvested in January. In the 2014/2015 cycle the harvest began in November and ended in December in most of the cultivars (Table 1).

The variation in the harvesting periods can be associated with the variations of temperature, mainly in August and September, when the flowering was beginning. The average temperature in August 2013 was 2 °C lower than observed in 2012 and 1.1 °C lower than 2014. The minimum temperature in this month was 3.3 °C lower than observed in 2012 and 1.3 °C lower than 2014 (Figure 2). These low temperatures in 2013 caused a delay in the flowering period and consequently in the harvest period too (Table 1), mainly because these low temperatures occurred in the final phase of dormancy (ecodormancy) or after flowering. The climatic factors act differently according to the development phase of the plant, determining the production potential (Antunes et al., 2012).

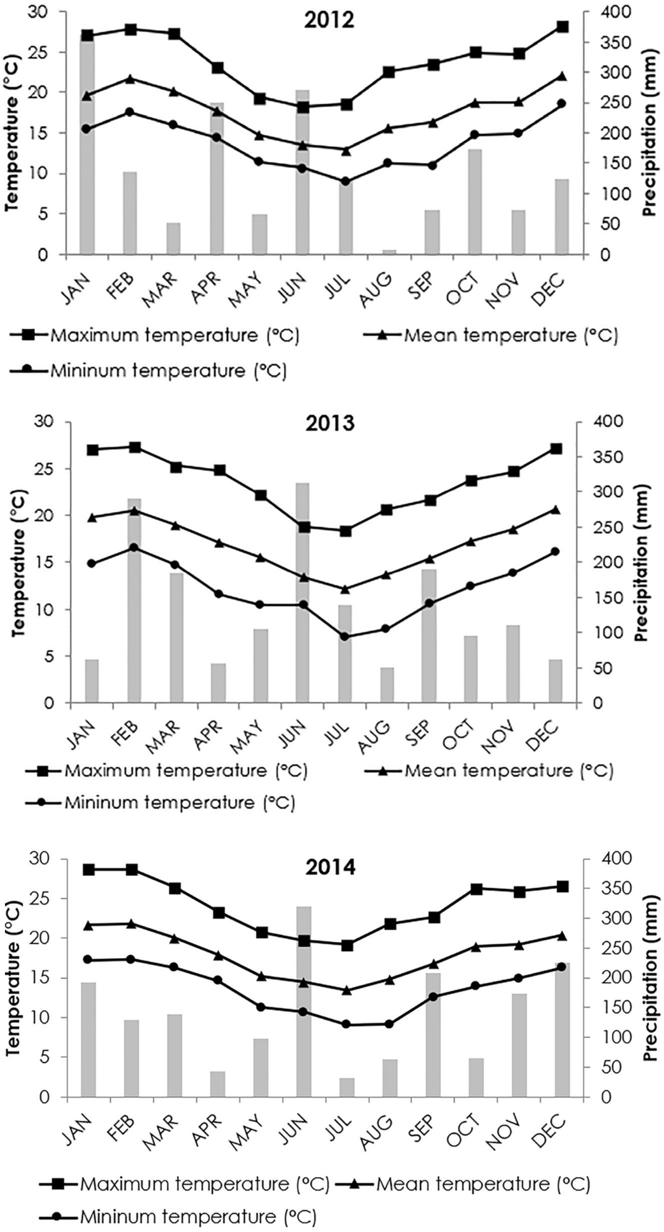

Figure 2. Climatic characteristics in 2012, 2013 and 2014 in Lapa, PR, Brazil. Climatic data collected in Lapa Meteorological Station from SIMEPAR.

In the first cycle, the average production was 11 g plant^{-1}, due to plants are only one year old (Table 2). In the second cycle, the cultivar Bluegem was the most productive and there was no production difference between the other cultivars (Table 2). This cultivar presented the highest yields in the three evaluated cycles, reaching the production of 1215 g plant^{-1} in the third cycle (Table 2), value similar (1250 g plant^{-1}) found by Fischer et al. (2014) in Pelotas, RS. In Cerro Azul, PR, 'Bluegem' was the most productive cultivar reaching 1091 g plant^{-1} in the third cycle (Medeiros et al., 2018). The greater yield of 'Bluegem' may be associated to the good vegetative vigor of this cultivar, which resulted in a greater capacity of supplying water and nutrients to the fruit, which may be due to than more vigorous plants with greater vegetative development are more productive (Pasa et al., 2014). Cultivars Georgiagem and O'Neal, from the highbush group, presented the lowest yields and did not produce in a few years, showing a lack of adaptation in the evaluated region, probably related to the insufficient chilling during dormancy period. This response was also observed in the region of Pelotas, RS for these cultivars, even with the occurrence of 368 chilling hours (Pasa et al., 2014). Cultivars of the highbush group generally require between 650 and 850 chilling hours (Strik, 2007). The cultivar Aliceblue, although belonging to the rabbiteye group, was also very unproductive, presenting no potential for cultivation at this site. This cultivar also showed the worst performance in Cerro Azul, PR (Medeiros et al., 2018).

The cultivars Climax, Delite and Powderblue also stood out with productions superior to 500 g plant^{-1} in the third year (Table 2). Medeiros et al. (2017) recorded that these cultivars, together with 'Bluegem', were also the most productive in the third year in Pinhais, PR. In the evaluation of cultivars of the rabbiteye group, Yu et al. (2006) obtained increasing productions from 500 to 1000 g plant^{-1} in the third year after planting and from 2000 to 3000 g plant^{-1} in the fourth year. Antunes et al. (2008) also observed differences between the yields of seven blueberry cultivars of this same group, with variation of 350 to 1630 g plant^{-1}. These differences in production may be a consequence of the difference in vigor between cultivars, pollination and intrinsic factors to plant adaptation, such as the requirement of low temperatures and local climatic variations.

In the 2012/2013 cycle, the cultivars Bluegem and Delite presented fruits with larger masses and were part of the group of cultivars with larger fruit size. In the following cycle there was no difference between the cultivars in the size of fruits, although the cultivars Bluegem and Climax presented the fruits with the highest mass (Table 2).

Differences were observed among cultivars regarding pH, soluble solids content and acidity in the three evaluated cycles. In general, the pH was low, with averages of all cultivars of 2.94, 3.19 and 2.86 in the 2012/2013, 2013/2014 and 2014/2015 crops, respectively (Table 2). The results found in the present study are greater than the range of 2.56 to 2.67 determined by Moraes et al. (2007) in the processing of blueberry food products. Soluble solids (SS) contents of the cultivars were very close, with averages of 11.15 °Brix, 11.35 °Brix and 12.16 °Brix in the three evaluated cycles (Table 2), a result close to the 10.1 to 13.27 °Brix observed by Medeiros et al. (2017) in Pinhais, PR, similar observed in Cerro Azul, PR, that ranged from 11.01 to 13.61 °Brix (Medeiros et al., 2018) and 12.4 to 14.5 °Brix found by Fischer et al. (2014) in genotypes selections with higher levels of SS between progenies in Pelotas, RS.

Table 2. Yield, berry weight, berry size, pH, soluble solids content (SS), titratable acidity (TA) and *ratio* (SS/TA) of blueberry cultivars, in the cycles 2012/2013, 2013/2014 and 2014/2015), in Lapa, PR, Brazil[1].

Cultivar	Yield (g.pl^{-1})	Berry weight (g)	Berry size (mm)	pH	SS (°Brix)	TA (% citric acid)	*Ratio* (ST/AT)
				2012/2103			
Aliceblue	--	--	--	--	--	--	--
Bluebelle	--	--	--	--	--	--	--
Bluegem	27.78a	1.19a	13.10a	2.94b	11.85b	0.74d	15.91a
Briteblue	2.66e	1.00b	12.68a	2.97a	12.37b	0.75d	16.48a
Climax	7.78d	0.96b	12.36a	3.02a	10.92c	0.82c	13.19c
Delite	11.69c	1.08a	12.60a	2.85c	13.75a	0.97b	14.09b
Georgiagem	2.67e	0.74c	11.44b	2.93b	10.87c	0.86c	12.59c
O'Neal	--	--	--	--	--	--	--
Powderblue	23.77b	0.71c	10.36c	2.80c	11.90b	1.09a	10.87d
Woodard	9.09d	0.67c	10.67c	2.91b	14.26a	1.12a	12.71c
Average	11.00	0.84	11.46	2.94	11.15	0.89	12.53
CV(%)	9.33	9.03	4.34	2.14	4.24	3.62	6.35
				2013/2104			
Aliceblue	--	--	--	--	--	--	--
Bluebelle	63.85b	1.33b	13.65a	3.27a	10.25d	0.80b	12.73b
Bluegem	360.82a	1.49a	13.61a	3.11c	11.62b	0.80b	14.42a
Briteblue	42.29b	1.28b	13.54a	3.30a	11.67b	0.90a	12.97b
Climax	60.73b	1.49a	14.03a	3.17b	11.02c	0.75b	14.85a
Delite	--	--	--	--	--	--	--
Georgiagem	--	--	--	--	--	--	--
O'Neal	--	--	--	--	--	--	--
Powderblue	48.03b	1.25b	13.06a	3.22a	12.30a	0.84b	14.48a
Woodard	58.09b	1.33b	13.41a	3.05c	11.27b	0.98a	11.42b
Average	105.63	1.36	13.55	3.19	11.35	0.85	13.48
CV(%)	13.93	10.27	3.65	1.46	4.08	6.94	8.15
				2014/2105			
Aliceblue	19.22f	1.67b	14.30a	2.77c	10.70b	0.76b	14.17c
Bluebelle	109.89e	1.64b	15.25a	2.60d	10.50b	1.14a	9.24d
Bluegem	1215.32a	1.66b	14.33a	2.82c	12.75a	0.61c	20.65b
Briteblue	85.88e	1.71b	14.24a	3.04b	12.45a	0.79b	15.74c
Climax	685.96b	1.66b	13.91a	2.89c	12.75a	0.72b	18.26b
Delite	586.62c	1.60b	13.83a	2.79c	12.65a	0.84b	14.94c
Georgiagem	65.41f	1.48c	14.13a	2.80c	12.65a	0.71b	17.73b
O'Neal	31.71f	2.07a	12.40a	3.32a	12.00a	0.45d	26.17a
Powderblue	528.92d	1.49c	13.65a	2.90c	12.20a	0.71b	16.99b
Woodard	125.42e	1.52c	14.21a	2.68d	12.97a	1.17a	11.08d
Average	345.43	1.65	14.02	2.86	12.16	0.79	16.50
CV(%)	8.61	4.26	6.82	2.83	6.48	8.63	12.52

[1] Means followed by the same letters in the columns do not differ by the Scott-Knott test (p≤0.05).

Mean values of the titratable acidity of 0.89, 0.85 and 0.79 % of citric acid (Table 2) evaluated in the first, second and third cycle respectively, were higher than the average of 0.72% citric acid determined by Pelegrine et al. (2012) in fruits of 'Climax' in the elaboration of jellies and inferior to the average of 1,28% determined by Rodrigues et al. (2007). The varied results confirm that the titratable acidity is dependent of the cultivar (Souza et al., 2014).

The SS/AT (ratio) relation was increasing throughout the seasons, reaching the highest ratio in the third evaluated cycle (16.50). This result is mainly due to the 'Bluegem', which presented the highest ratio (20.65) due to the low acidity (0.61% citric acid). The response variability of the blueberry, depending on the year, was also observed in several experiments with cultivars of the highbush and rabbiteye group in the United States (Gündüz et al., 2015) and Brazil (Antunes et al., 2008; Medeiros et al., 2017; Medeiros et al., 2018).

Average values of luminosity (L*) of 31.97, 33.32

and 33.24 obtained in the three evaluated crops indicate low fruit luminosity (Table 3), similar to that found by Medeiros et al. (2017) in Pinhais, PR and by Concenço et al. (2014) with Bluegem cultivar, produced in Antônio Carlos, MG. The low luminosity can be consequence of the loss of the pruine, wax that recovers the fruits when mature (Canturias-Avilés et al., 2014), which gives a brighter appearance to the fruits. According to Sousa et al. (2007) the environment in which the fruits develop also affects their coloration. Color is influenced by the presence of epicuticular wax, that is responsible for the typical blue color of the fruits, by the presence of anthocyanins and the place where the fruit develops (Maro et al., 2014).

The color of the fruits presented little variation among the cultivars, with averages of a* of 4.29, 3.53 and 1.14 in the three evaluated cycles (Table 3), tending towards red. For the coordinate b*, the values were between -5.65, -7.88 and -4.16 in three cycles, tending towards blue. This same coloring tendency also occurred for these cultivars when evaluated in Pinhais, PR (Medeiros et al., 2017). Visually the color of the epidermis of the fruits is initially green passing through the red and bluish when ripe. The mean values of h*, which represent the color tone of the fruits, were -0.93, -1.14 and -1.29, presenting little variation in the three cycles evaluated. The lower angle represents greater intensity, the range of color between red and blue, representing purple (Concenço et al., 2014). For saturation, which represents the intensity of the tonality, the mean values were among 7.37, 8.70 and 4.45, respectively in the cycles 2012/2013, 2013/2014 and 2014/2015 (Table 3). This tendency also was observed in Cerro Azul, PR, for same years, probably affected by climatic conditions.

Table 3. Color parameters (L*, a*, b*), tonality (hue) e saturation of blueberry cultivars, in the 2012/2013, 2013/2014 and 2014/2015 cycles, in Lapa, PR, Brazil(1).

Cultivar	Color parameters			Tonality	Saturation
	L*	a*	b*	Hue(2)	Chroma
			2012/2103		
Aliceblue	--	--	--	--	--
Bluebelle	--	--	--	--	--
Bluegem	31.09c	3.34b	-6.23a	-1.07a	7.10c
Briteblue	35.91a	7.59a	-5.47b	-0.68a	10.14a
Climax	29.72c	4.88b	-4.52b	-0.75a	6.75c
Delite	32.97b	4.22b	-6.23a	-0.97a	7.63b
Georgiagem	33.78b	3.03b	-7.50a	-1.18a	8.14b
O'Neal	--	--	--	--	--
Powderblue	36.26a	4.48b	-6.85a	-0.99a	8.23b
Woodard	28.51d	3.61b	-3.88b	-0.83a	5.35d
Average	31.97	4.29	-5.65	-0.93	7.37
CV(%)	4.78	38.50	23.46	23.67	13.10
			2013/2104		
Aliceblue	--	--	--	--	--
Bluebelle	32.54b	4.69a	-6.38c	-0.94b	7.98b
Bluegem	33.90b	3.13b	-8.33b	-1.21a	8.90b
Briteblue	32.47b	3.09b	-7.88b	-1.19a	8.48b
Climax	29.75c	3.43b	-7.19c	-1.12a	7.97b
Delite	--	--	--	--	--
Georgiagem	--	--	--	--	--
O'Neal	--	--	--	--	--
Powderblue	38.37a	3.21b	-9.69a	-1.24a	10.21a
Woodard	32.91b	3.66b	-7.82b	-1.13a	8.64b
Average	33.32	3.53	-7.88	-1.14	8.70
CV(%)	3.12	16.03	8.32	5.98	7.44

Continue...

			2014/2105		
Aliceblue	32.43c	1.32a	-5.19a[3]	-1.50a	5.21b
Bluebelle	36.98a	1.37a	-5.61a	-1.27a	6.50a
Bluegem	35.24b	1.07b	-4.94a	-1.40a	5.02b
Briteblue	32.09c	0.92b	-3.87b	-1.20a	4.18c
Climax	31.11c	1.07b	-3.41b	-1.32a	3.51d
Delite	33.37c	1.52a	-4.26a	-1.47a	4.29c
Georgiagem	30.67c	1.14b	-2.50b	-1.12a	2.80d
O'Neal	32.15c	1.05b	-4.26a	-1.35a	4.38c
Powderblue	34.06b	1.08b	-4.35a	-1.33a	4.55c
Woodard	34.31b	0.86b	-3.17b	-1.00a	4.06c
Average	33.24	1.14	-4.16	-1.29	4.45
CV(%)	4.37	24.63	23.45	20.49	16.42

[1] Means followed by the same letters in the columns do not differ by the Scott-Knott test ($p \leq 0.05$).

[2] Data in radians.

[3] Original transformed data ($x = \sqrt{\ }$)

Conclusions

The flowering period of the blueberry cultivars occurs from July to September, concentrating the harvest in the months of November and December.

The most productive blueberry cultivar in subtropical climate of altitude is the Bluegem, followed by cultivars Climax, Delite and Powderblue.

Acknowledgements

To Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and to Araucária Foundation for financial support for the development of the project and the IDR by the physical and technical structure.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.