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CIÊNCIAS AGRÁRIAS

Blueberry (Vaccinium ashei Reade) cv. Powderblue: productive and physicochemical characterization

***Mirtilo (Vaccinium ashei Reade) cv. Powderblue**: caracterização produtiva e físico-química*

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ABSTRACT

Blueberry cultivation has gained significant attention due to its bioactive profile and antioxidant potential. The productive characteristics of blueberry plants play a crucial role in influencing the quantity and quality of the fruits produced. Therefore, the objective of this study was to evaluate the productive characteristics and their impact on the physicochemical profile of the blueberry cultivar Powderblue over two harvest seasons. The study revealed that there was a greater number of flowering buds interspersed with vegetative buds at the apical level of the shoots. The presence of floral primordia was more prominent in the medial and apical shoot levels, and this influenced the distribution of flowers and fruits, which were found in higher quantities at the apical shoot level. During both harvest seasons, the fruits located at the apical shoot level exhibited higher levels of soluble solids, phenolic compounds, anthocyanins, and antioxidant potential. They also had a higher pH and lower acidity compared to the fruits located at the medial and basal shoot levels. The positions of the flowering and vegetative buds had a direct impact on the abundance of floral primordia, flowers, and fruits. This, in turn, was closely associated with the antioxidant activity, total phenolic compounds, total anthocyanins, and physicochemical parameters of the fruits.

Keywords: phenolic compounds; total anthocyanins; production habit.

RESUMO

O cultivo do mirtilo tem atraído atenção devido ao seu perfil bioativo, e potencial antioxidante, sendo que suas características produtivas influenciam no número e na qualidade dos frutos produzidos. O objetivo foi avaliar as características produtivas e sua influência no perfil físico-químico do mirtilo cv. Powderblue por dois anos. Observou-se maior número de botões florais intercalados com botões vegetativos no nível apical. Os primórdios florais foram encontrados em maior número nos níveis medial e apical do caule e influenciaram as posições de flores e frutos que foram encontrados em maior quantidade no nível apical do caule. Em ambas as safras, os frutos localizados no nível apical apresentaram maior teor de sólidos solúveis, compostos fenólicos, antocianinas, potencial antioxidante, pH e menor acidez do que os frutos localizados nos níveis mediano e basal. A posição dos botões florais e vegetativos impacta o nível e o número de primórdios florais, flores e frutos, e está diretamente relacionada à atividade antioxidante, compostos fenólicos totais, antocianinas totais e parâmetros físico-químicos dos frutos.

***Palavras-chave**: compostos fenólicos; antocianinas totais, hábito de produção.*

1. INTRODUCTION

The cultivation of blueberries (Vaccinium spp.) has gained significant attention among small farmers due to innovative cultivation techniques and the high added value of the fruits. This crop presents a profitable alternative source of income for these farmers. (RADÜNZ *et al.*, 2016; LUO *et al.*, 2018). Furthermore, blueberries have become increasingly popular among consumers due to their appealing flavor and rich bioactive profile. Blueberries are known for their abundance of phenolic compounds and anthocyanins, which offer various health benefits to human health. (ZHANG *et al.*, 2019).

Among the blueberry groups, Rabbiteye (Vaccinium ashei Reade) has been widely cultivated. Within the cultivars encountered in this group of blueberries, there is the cultivar Powderblue. This cultivar originated in the United States and is characterized by its vigor, high yields, good resistance to diseases, and low demand for cold temperatures. (PASA *et al.*, 2014).

Because it is native to the United States, Powderblue is considered an exotic species for the edaphoclimatic conditions of Brazil, which raises the need for the evaluation of its productive behavior. In addition to the genetic factors that may affect the productive characteristics of the cultivar, edaphoclimatic factors promote strong interference with the quality of the harvested fruits, changing both its dimensions and its physicochemical composition, which in turn affects its biological functions after consumption. (GÜNDÜZ *et al.*, 2015).

The behavior of plants, including the type, number, and position of flowering and vegetative buds, is strongly influenced by climatic conditions. These factors play a vital role in the adaptation of plants and significantly impact the quantity and nutritional quality of the fruits produced. As a result, even within the same cultivar, variations in the number of flowering buds, flowers, and fruits can be observed depending on the specific edaphoclimatic conditions in which the plants are grown. (RADÜNZ *et al.*, 2018). Understanding how plants respond to different edaphoclimatic conditions is crucial for effective management practices and maximizing yields and fruit quality.

To obtain a better understanding of the bioclimatology of blueberries cultivated in southern Brazil and the relationship between fruiting and productive habits in this region, it is crucial to characterize the specific cultivar grown in this area. This will allow the generation of new management practices to obtain greater yields and fruits with better quality. Therefore, the objective of this study was to evaluate the influence of the position and distribution of vegetative and flowering buds, floral primordia, and flowers on the productivity and physicochemical fruit parameters of the blueberry cultivar Powderblue.

2. MATERIAL AND METHODS

2.1. DATA ACQUISITION

Data were collected in two consecutive harvest seasons (2012/2013 and 2013/2014) from an eight-year-old commercial orchard located in Morro Redondo City, RS (31º32'S 52º34'O, altitude 150 meters). The orchard is cultivated with plants of the cultivar Powderblue in full production. Climatological data for the period from 1971 to 2000 shows that the region where the orchard is located has an average annual rainfall of 1366.9 mm, and a temperature of 17.8 ºC. The average temperature of the hottest month is 23.2 ºC, in January.

2.2. EXPERIMENTAL DESIGN

A totally random experimental design conducted under a 2 × 2 factorial scheme (shoot length × harvest season) was adopted to analyze the distribution of vegetative and flowering buds in the shoots. For the characterization of the number of floral primordia, number of open flowers and number of developed fruits, an experimental design was carried out in a 2 × 3 × 2 factorial scheme (shoot length × bud position in the shoot × harvest season).

For the analysis of all the variables, four groups of plants were randomly selected. Each group consisted of four plants, of which the two central plants were selected. From each group, 10 long-length (31 to 50 cm) and 10 short-length shoots (15 to 30 cm) were randomly selected per plant in each harvest season.

Shoots were grouped in two length sizes because of the greater precision in the interpretation of the results and because it eases the use of these results for the management of the plants. Blueberry orchards have a predominance of these shoot sizes in the plants of the cultivar.

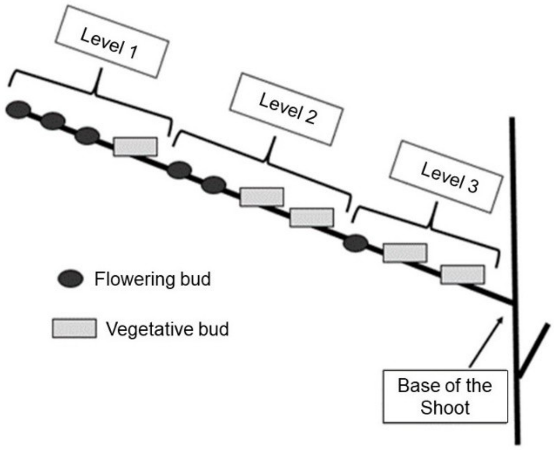
2.3. BLUEBERRY EVALUATION

On The assessment of the number and position of flowering and vegetative buds was carried out on predefined and randomly selected shoots. Additionally, observations were made on the same shoots to determine the number of flowers that opened during the flowering period and the number of fruits that developed until the end of the harvest season. These observations were conducted on a weekly basis.

To evaluate the number of floral primordia, shoots were sampled on five different dates, ranging from leaf senescence to flower opening. These evaluations took place between the months of April and August during each harvest season. For each group of plants, 10 long-length shoots and 10 short-length shoots were collected on each evaluation date. The collected shoots were then transported to the fruit laboratory of the Federal University of Pelotas. In the laboratory, the apical, medial, and basal buds of the shoots were dissected to determine the number of floral primordia. This process was performed for each level of the shoots (apical, medial, and basal). At the end of the harvest season, the average number of floral primordia was calculated for each shoot level.

To determine the total number of flowering and vegetative buds in long- and short-length shoots, counts were conducted, and the results were weighted based on the presence of buds in the different shoot levels. These levels were characterized by the arrangement of flowering and vegetative buds, as illustrated in Figure 1. To prevent overestimation of the total bud count, a weighting approach was implemented. The flowering and vegetative buds occupying the first position, which corresponds to the apical level at the terminal part of the shoot, were multiplied by a weight of 1.0 because these buds were present in all 10 shoots that were evaluated. For the buds occupying the second position (medial level) and subsequent levels, the respective counts were multiplied by the fraction representing the number of shoots in which they were observed. For example, if these buds were present in six out of the 10 shoots, the count was multiplied by 0.6. The same weighting procedure was applied to buds in the subsequent levels.

Figure 1 – Representation of the levels used to characterize the fruiting habit for the three blueberry cultivars grown in Morro Redondo, RS. Where: level 1 – the apical level; level 2 – the medial level; and level 3 – the basal level.



Source: the authors.

2.4. PHYSICOCHEMICAL PROFILE

Blueberry fruits from the apical, medial, and basal levels, during both harvest seasons, were subjected to drying in an air circulation oven at a constant temperature of 37 °C until they reached a constant weight. Thereafter, the dried fruits were ground using a ball mill. To determine the content of soluble solids, acidity, pH, phenolic compounds, anthocyanins, and antioxidant potential, 2 g of the resulting blueberry powder was weighed and homogenized in 20 ml of deionized water.

The content of soluble solids, measured in °Brix, was determined using a refractometer (Quimis model Q-109B). The pH of the blueberry samples was measured using a potentiometer (New Technical Ind. And Com. Brazil). The acidity of the fruits was evaluated following the methodology proposed by the AOAC method (2001) and expressed as a percentage.

For the determination of total phenolic compounds, the method described by Swain and Hillis (1959) was employed with certain adaptations, and the results were expressed in milligrams of gallic acid per 100 grams of fruits. The anthocyanin content was determined using the method developed by Lees and Francis (1972) with specific modifications, and the results were expressed in milligrams of cyanidin-3-glycoside per 100 grams of fruits.

Lastly, the antioxidant potential of the blueberry samples against the 2,2-diphenyl-1-picryl-hydrazyl (DPPH) radical was evaluated following the procedure outlined by Brand-Williams et al. (1995), with certain adaptations. The antioxidant potential results were expressed in micromoles of Trolox equivalent per 100 milligrams of fruits.

2.5. STATISTICAL ANALYSIS

The data obtained for the total number of flowering and vegetative buds, as well as the number of floral primordia, flowers, fruits, and the results of the physicochemical analyses, were subjected to analysis of variance (ANOVA). If the means showed significant differences, Tukey's HSD test was performed for multiple comparisons. The significance level for all tests was set at $p \leq 0.05$.

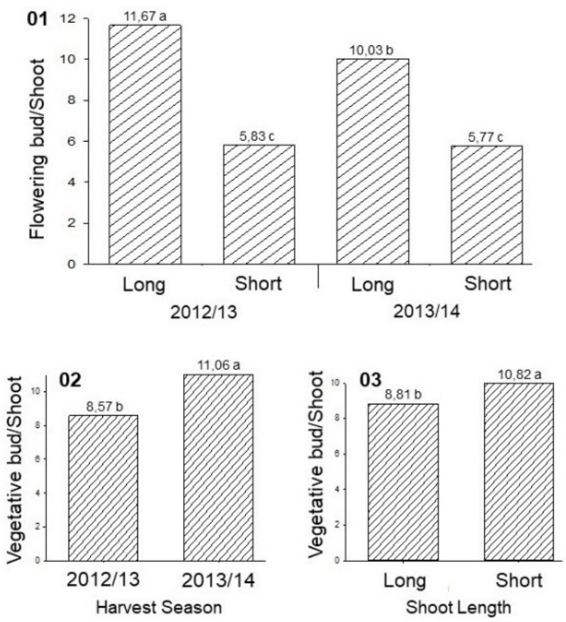
3. RESULTS AND DISCUSSION

3.1. NUMBER AND DISTRIBUTION OF FLOWERING AND VEGETATIVE BUDS

The findings of Radünz (2018) indicate that flowering buds of blueberries are typically located at the apical level of the shoot, while vegetative buds are predominantly found at the basal level. However, in this particular study, it was observed that Powderblue blueberries exhibited a different pattern. Both flowering and vegetative buds were interspersed along the shoot length, as shown in Figure 2. This distribution of buds in Powderblue blueberries could be attributed to the mild winter climatic conditions prevalent in the mesoregion where the study was conducted. These conditions may have favored the differentiation of vegetative buds into flowering buds, leading to the observed pattern.

Analyzing the data from both harvest seasons, it was found that the long-length shoots generally exhibited a higher number of flowering buds compared to the short-length shoots (Figure 2.01). On the other hand, the total number of vegetative buds was higher in the 2013-2014 harvest season, regardless of the shoot length (Figure 2.02). Additionally, long-length shoots consistently had a greater number of vegetative buds in both harvest seasons (Figure 2.03).

Figure 2 – The total average number of flowering buds as a function of the interaction between the shoot length and harvest season (01), the total average number of vegetative buds as a function of the harvest season (02), and as a function of the shoot length (03). Means followed by the same letter do not differ from each other according to Tukey's HSD test (p≤0.05). CV: 4.00% (1) and 5.34% (2 and 3).



Source: the authors.

According to the data presented in Table 1, the assessment of interspersed vegetative and flowering buds in each shoots level revealed that, on average, for the 10 shoots evaluated, 42% (4.2 buds) and 37% (3.7 buds) of the buds were found to be interspersed at the second level in the long- and short-length shoots, respectively. For the third level, only 8% (0.8 buds) and 7% (0.7 buds) were interspersed in the long- and short-length shoots, respectively.

Analyzing the average distribution of buds across the different levels, a higher number of flowering buds were observed in the first level. On average, 9.3 flowering buds were found in the long-length shoots, representing 85% of the total flowering buds in those shoots. Similarly, 5.0 flowering buds were observed in the short-length shoots, representing 86% of the total flowering buds in those shoots.

It is evident that while flowering buds are interspersed with vegetative buds in both shoot lengths, most of the flowering buds are concentrated in the first level of the shoots. Looking at the average number of each bud type, there were 10.9 flowering buds and 10.8 vegetative buds in the long-length shoots, while the short-length shoots had 5.8 flowering buds and 8.8 vegetative buds (Table 1). This totals to an average of 21.7 buds in the long-length shoots and 14.6 buds in the short-length shoots. The ratio of vegetative buds to flowering buds was approximately 1.00 for the long-length shoots and 1.52 for the short-length shoots.

Table 1 – Characterization of bud distribution for each level, and the average number of flowering and vegetative buds for the cultivar Powderblue, 2012/2013 and 2013/2014 harvest seasons, Pelotas, RS.

Harvest Season	Shoot size	Level 1			Level 2			Level 3			Total		Total number of buds
		NS	F	V	NS	F	V	NS	F	V	F	V	
2012/2013	Long	10	10.3	6.7	4.0	3.3	6.8	0.3	0.3	2.0	11.7	9.6	21.3
2013/2014		10	8.3	8.0	4.3	3.5	7.5	1.3	0.7	2.1	10.0	12.0	22.0
2012/2013	Short	10	5.2	6.0	3.0	2.1	4.9	Nd	nd	nd	5.8	7.5	13.3
2013/2014		10	4.8	6.6	4.3	1.8	5.9	1.3	0.8	4.8	5.8	10.1	15.9
Average Long		10	9.3	7.4	4.2	3.4	7.2	0.8	0.5	2.0	10.9	10.8	21.7
Average Short		10	5.0	6.3	3.7	1.9	5.4	0.7	0.4	2.4	5.8	8.8	14.6

Source: The authors. Legend: Average of 3 plants (30 shoots). Number of shoots (NS) in which the levels are present; Number of flowering buds (F) for the level; Number of vegetative buds (V) for the level.

These results demonstrate that this cultivar can better adapt to the edaphoclimatic conditions of Pelotas when compared to the cultivar Climax evaluated under the same climatic conditions (Radünz *et al.,* 2018). Better adaptability to growing conditions promotes an increase in the number of fruits, as well as a greater expression of bioactive compounds, such as anthocyanins and organic acids that have proven biological activities in the human body, acting in the reduction of chronic non-communicable diseases, such as cancer, type II diabetes mellitus and cardiovascular diseases. (LUO *et al.,* 2018; ZHANG *et al.,* 2019).

3.2. NUMBER OF FLORAL PRIMORDIA

Based on the data presented in Table 2, the number of floral primordia varied significantly depending on the interaction between the shoot length, harvest season, and the position of the bud. For the 2012/2013 harvest season, there was a significant difference in the number of floral primordia between short- and long-length shoots at all three levels evaluated. In the 2013-2014 harvest season, there was a significant difference in the number of floral primordia between short-length shoots at all three levels evaluated. However, for the long-length shoots, a significant difference was observed only at the medial level. Regarding the harvest seasons, there were no significant differences in the number of floral primordia between the levels.

Table 2 – The number of floral primordia as a function of the interaction between shoot length, harvest season, and the bud position for the blueberry cultivar Powderblue. Pelotas/RS.

Shoot (S) X Harvest Season (H)	Bud Position		
	Apical	Medial	Basal
Short-length shoot – Harvest 2012/2013	8.43 aA	8.05 bB	7.71 bC
Short-length shoot – Harvest 2013/2014	8.44 aA	8.08 bB	7.76 bC
Long-length shoot – Harvest 2012/2013	8.28 aB	8.50 aA	8.12 aC
Long-length shoot – Harvest 2013/2014	8.28 aB	8.53 aA	8.15 aB

Source: the authors. Legend: Same lowercase letters in the column and uppercase letters in the line represent means that are not statistically different according to Tukey's HSD test ($p \leq 0.05$).

In the long-length shoots, for both harvest seasons, the highest number of floral primordia was found at the medial level. For the short-length shoots in both harvest seasons, the highest number of floral primordia was encountered at the apical level. These results are different from those found for the cultivar Climax grown under the same climatic conditions (RADÜNZ *et al.,* 2018), where the authors observed a greater number of floral primordia at the basal level of shoots. The number of flower primordia is important to be assessed as it predetermines the number and position of flowers that will be produced by the plant. This directly impacts the yield and physicochemical quality of the fruits.

3.3. NUMBER OF FLOWERS

Based on the data provided in Table 3, it can be observed that the number of flowers varied depending on the shoot length, the harvest season, and the level of the buds. When comparing the number of flowers between shoot lengths, regardless of the harvest season, there was a significant difference for all levels. In all cases, the apical level had the highest number of flowers. There was also a significant difference between shoot lengths and harvest seasons for the apical level. The long-length shoots had the highest number of flowers during the 2012/2013 harvest season. For the medial level, there were no statistical differences between the long-length shoots for both harvest seasons. Regarding the basal level, there was a significant difference between short-length and long-length shoots and the harvest seasons. The long-length shoots during the 2012/2013 harvest season had the largest number of flowers.

Table 3 – The number of flowers as a function of the interaction between the shoot length and the bud position for the blueberry cultivar Powderblue. Pelotas/RS.

Shoot	Bud Position		
	Apical	Medial	Basal
Short-length shoot – Harvest 2012/2013	7.70cA	7.35bB	6.75cC
Short-length shoot – Harvest 2013/2014	7.38dA	7.20cB	6.49dC
Long-length shoot – Harvest 2012/2013	8.05aA	7.65aC	7.75aB
Long-length shoot – Harvest 2013/2014	7.78bA	7.64aB	7.49bC

Source: the authors. Legend: Same lowercase letters in the column and uppercase letters in the line represent means that are not statistically different according to Tukey's HSD test ($p \leq 0.05$).

It is interesting to note that in the present study, the flowers were found in greater quantity at the apical level (2012/2013), while in the study by Radünz *et al.* (2018) for the cultivar Climax, a greater number of flowers was reported at the medial level. These differences in flower distribution between the two studies could be attributed to genetic variation, environmental conditions, and management practices.

3.4. NUMBER OF FRUITS

The number of fruits produced in each level of the shoot is presented in Table 4. When comparing the number of fruits at each level as a function of the shoot length, regardless of the harvest season, a significant difference was observed between the lengths for all levels. In all cases, the largest number of fruits was found at the apical level, similar to what was observed for the number of flowers.

Table 4 – The number of fruits as a function of the interaction between the shoot length and the bud position for the blueberry cultivar Powderblue. Pelotas/RS.

Shoot	Bud Position		
	Apical	Medial	Basal
Short-length shoot – Harvest 2012/2013	7.60aA	5.65aB	3.70cC
Short-length shoot – Harvest 2013/2014	7.28bA	4.52dB	2.72dC
Long-length shoot – Harvest 2012/2013	7.26bA	5.55bB	5.10aC
Long-length shoot – Harvest 2013/2014	6.77cA	4.91cB	4.76bC

Source: the authors. Legend: Same lowercase letters in the column and uppercase letters in the line represent means that are not statistically different according to Tukey's HSD test ($p \leq 0.05$). Harvest = H (H1 = 2012/13; H2 = 2013/14). Shoot = S (SS = Short; SL = Long).

Comparing the short- and long-length shoots for the apical level of the shoots in both harvest seasons, no significant differences were found between the short length for the 2013-2014 harvest season and the long length for the 2012/2013 harvest season. However, for the medial level, there was a significant difference between all shoot lengths and harvest seasons, with the largest number of fruits observed in the short-length shoots for the 2012/2013 harvest season. Similarly, at the basal level, there was a significant difference between shoot lengths and harvest seasons, with the highest number of fruits found in the long-length shoots for the 2012/2013 harvest season. Notably, the highest number of independent fruits, considering the shoot length, was found at the apical level of short-length shoots for the 2012/2013 harvest season. This is consistent with the findings reported by Radünz *et al.* (2018) for blueberries of the Climax cultivar.

3.5. PHYSICOCHEMICAL PROFILE

The analysis of the fruits' soluble solids content (Table 5) revealed a significant difference between the harvest seasons and the shoot levels. In the 2012/2013 harvest season, fruits from the apical level exhibited a higher content of soluble solids, while in the 2013/2014 harvest season, the fruits from the medial level showed the highest content. It is noteworthy that the soluble solids content obtained in our study, across all levels and harvest seasons, exceeded the values reported by Pertuzatti *et al.* (2016) in their study on blueberry cultivar Powderblue grown in the Porto Alegre mesoregion of Brazil. The soluble solids content reported by Pertuzatti et al. ranged from 10.3° to 15.5 °Brix.

The measurement of soluble solids is a parameter of fruit maturation that can determine the sweetness of the fruit, as it measures the content of sugars, organic acids, and tannins. For blueberries, values equal to or greater than 15 °Brix indicate an optimal stage of maturity, therefore, in our study, blueberries of all levels and from both harvest seasons were in an adequate stage of maturity.

The harvest season and the shoot level significantly influenced the percentage of acidity of the fruits (Table 5). The acidity values found for all levels in both harvest seasons were slightly lower than the values of 0.43% to 0.57% found in the blueberry cultivar Powderblue produced in the mesoregion of Porto Alegre. (PERTUZATTI *et al.* 2016). The percentage of acidity is directly correlated with the content of soluble solids because, during fruit ripening, there is an accumulation of sugars (increase in soluble solids) and consequently a decrease of acidity, as observed in our study.

The pH of the fruits (Table 5) in the 2012/2013 harvest season only showed a statistical difference for the fruits of the apical level, with higher values. In the 2013/2014 harvest season, none of the levels differed from each other. Evaluating the harvest seasons, only the fruits of the apical level did not show a significant difference, with the 2013/2014 harvest season showing higher pH values for the fruits of the medial and basal levels.

A study that evaluated the blueberry cultivar Powderblue produced in the mesoregion of Porto Alegre, Brazil found pH values ranging from 3.5 down to 2.9 in the 2010/2011 and 2011/2012 harvest seasons (Pertuzatti *et al.* 2016), values lower than those reported in our study. Low pH values help to retain phenolic compounds and anthocyanins, as these compounds are unstable at higher pH. Thus, the pH found in our study favors the preservation of bioactive compounds, increasing the nutritional potential of the fruits.

Table 5 – Physicochemical parameters of blueberry fruits from the cultivar Powderblue as a function of the bud position and the harvest seasons.

Parameter	Bud Position		
	Apical	Medial	Basal
Soluble solids 2012/2013	18.27Ab	16.00Bb	15.47Cb
Soluble solids 2013/2014	18.60Ba	18.80Aa	18.30Ca
Acidity 2012/2013	0.27Cb	0.40Ba	0.45Aa
Acidity 2013/2014	0.43Aa	0.37Bb	0.34Cb
pH 2012/2013	3.58Aa	3.32Bb	3.32Bb
pH 2013/2014	3.59Aa	3.60Aa	3.60Aa
Phenolic compounds 2012/2013	1664.7Aa	1586.3Ba	1564.4Ca
Phenolic compounds 2013/2014	1270.3Cb	1312.1Bb	1316.3Ab
Anthocyanins 2012/2013	68.2Aa	60.8Ba	57.6Ca
Anthocyanins 2013/2014	24.7Ab	17.1Cb	19.5Bb
Antioxidant potential 2012/2013	1700.0Aa	1600.0Ba	1600.0Ba
Antioxidant potential 2013/2014	1630.0Ab	1620.0Aa	1630.0Aa

Source: the authors. Legend: Soluble solids - ° Brix; Acidity - g of citric acid in 100g; Phenolic compounds - mg.eq. gallic acid in 100g; anthocyanins - mg eq. cyanidin-3-glycoside in 100g; Antioxidant potential - µmol eq. Trolox in 100g. Same lowercase letters in the column and uppercase letters in the line represent means that are not statistically different according to Tukey's HSD test ($p \leq 0.05$).

For the phenolic compounds content (Table 5), the fruits of all levels in both harvest seasons showed a significant difference, with the 2012/2013 harvest season having the highest content of phenolic compounds at the apical level and the 2013/2014 harvest season at the basal level. Evaluating the harvest seasons, all levels showed a statistical difference. The content of phenolic compounds found for all levels in both harvest seasons was higher than that reported in the literature, which brings values of 1.71-2.63 mg GAE/100g for the blueberry cultivar Powderblue produced in the China (GUOFANG *et al.,* 2019), and 14 to 19 mg GAE/100g for those produced in the Mexico. (BERNAL-GALLARDO *et al.*, 2022). The most prevalent phenolic compounds present in blueberries are chlorogenic acid, quercetin, caffeic acid, and p-coumaric acid.

The fruits of all levels and for both evaluated harvest seasons showed a statistical difference in terms of anthocyanin content (Table 5), with the highest values found at the apical level of shoots. Between the harvest seasons, there was a significant difference, with higher anthocyanin content in the 2012/2013 harvest season. The content of anthocyanins presented at all levels for both harvest seasons was lower than those reported in the literature. (GOWD *et al.,* 2017). The main anthocyanins present in blueberry of the cultivar Powderblue are cyanidin-3-galactoside, malvidin-3-galactoside, and petunidin-3-glucoside. These compounds have several proven benefits, such as digestive α-amylase and α-glucosidase enzyme inhibition, responsible for the hyperglycemia process related to type II diabetes mellitus. (GOWD *et al.,* 2017).

Finally, among the shoot levels of the 2012/2013 harvest season, a greater antioxidant activity (Table 5) was observed at the apical level, while there was no statistical difference between the fruits of the medial and basal levels. In the 2013/2014 harvest season, the shoot levels had no significant influence on the antioxidant activity. Between the harvest seasons, there was a significant difference only for the fruits of the apical level, with greater activity in the 2012/2013 harvest season. The antioxidant potential of blueberries found in our study, measured by the capture of the DPPH radical, was higher than that reported by Bernal-Gallardo *et al.* (2022) in the blueberry cultivated in Mexico.

Although slightly lower, the results demonstrate the potential of blueberries harvested from the three shoot levels and both harvest seasons to act in the capture of DPPH, inhibiting the excessive production of free radicals in the body, which are considered to be precursors of inflammatory processes and that can cause several chronic non-communicable diseases related to high morbidity and mortality. Although DPPH is not a reactive oxygen species (ROS) produced by the human body, its evaluation is consensual as a parameter for determining antioxidant activity due to the stability of its structure.

Phenolic compounds and anthocyanins present in blueberries are responsible for the antioxidant potential of the fruits. The inhibition of free radicals (ROS) is extremely important for the control and inhibition of various inflammatory processes. Studies point out that anthocyanins present in blueberries can act on the route of nuclear factor erythroid-2-related factor 2 (Nrf2), a regulator of cellular detoxification responses and redox status that controls inflammatory processes that can lead to neurodegenerative diseases, such as the Alzheimer's and Parkinson’s diseases. (SUKPRASANSAP *et al.,* 2020). The phenolic compounds of blueberries, on the other hand, may have a cardioprotective effect due to the control of inflammatory processes. (LUO *et al.,* 2018).

Possibly the differences between the contents of soluble solids, acidity, pH, phenolic compounds, anthocyanins, and antioxidant potential occur due to edaphoclimatic factors, which directly influence the expression of some bioactive compounds. For almost all parameters evaluated, fruits from the apical level were found with higher concentrations of these compounds. This can be explained by the higher incidence of solar radiation received by these fruits in comparison to the fruits from the medial and basal levels, which are closer to the crop canopy and receive a lower incidence of sunlight. (RADÜNZ *et al.,* 2018).

4. CONCLUSION

The distribution and level of flowering and vegetative buds directly impacted the number of floral primordia, which in turn affected the number of flowers, fruits, and their location in the shoot. Physicochemical characteristics such as soluble solids, acidity, pH, phenolic compounds, anthocyanins, and antioxidant potential were directly affected by the level where fruits were found. Fruits present at the apical level showed the best characteristics, possibly due to the higher solar radiation received. It is worth mentioning that the physicochemical data evaluated in our study are of great scientific relevance to help to 1) guide farmers and scientists as to the characteristics of the cultivar; 2) stimulate a more sustainable production of blueberry for the mesoregion of Pelotas, and consequently; and 3) expand the market for greater consumption of blueberries, which present several health benefits for human beings.

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