

Introduction and evaluation of blueberry cultivars for the state of Ceará

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Abstract

Blueberry is a crop commonly associated with temperate climates. Depending on the species, it may appear as semi-prostrate plants, shrubs, or small trees of varying heights. With the emergence of cultivars from the Southern Highbush group, several countries in the Southern Hemisphere have invested in blueberry cultivation, driven by global demand, economic profitability, and the versatile use of the fruit, especially considering its nutraceutical properties. Blueberries are a high-value fruit with strong market potential, which has led to increased local interest in cultivation, encouraged by state policies that promote crop diversification to enhance the value of agricultural production in the state. This study aims to provide data to support blueberry cultivation in the state of Ceará. Three blueberry cultivars (Biloxi, Biloxi XL, and Emerald) were evaluated under the climatic conditions of the Baturité massif region. Five morphological descriptors and nine productive descriptors were analyzed. Regarding productive aspects, 'Biloxi' achieved the best results in terms of fruit size and quantity. The Biloxi cultivar demonstrated greater hardiness under climatic conditions. Alternative cultivation systems to fertigation require further research, as inadequate practices may prevent cultivars from reaching their maximum productive potential.

Keywords: Added value, Protected cultivation, *Vaccinium corymbosum* L.

Introduction

Blueberry (*Vaccinium corymbosum* L.) originates from cold regions of Europe and North America, mainly the United States and Canada. It belongs to the Ericaceae family, Vaccinioideae subfamily, and the *Vaccinium* genus (Antunes & Raseira, 2006; Santos & Raseira, 2002). Blueberries are rich in vitamins A, B, C, and PP, as well as minerals such as magnesium, potassium, calcium, phosphorus, iron, manganese, and other compounds (Lima, 2021). Numerous medicinal properties are attributed to the fruit due to its antioxidants, flavonoids, polyphenols, and other phenolic compounds (Queiroga et al., 2021). It is a versatile fruit consumed fresh or processed into juices, jams, and even dietary supplements. The popularization of its health benefits has contributed to the increasing global demand (Antunes & Madail, 2005).

According to Silva & Melo (2021), the first experiments for blueberry introduction in Brazil were

conducted by Embrapa Clima Temperado in Pelotas/RS around 1983, using cultivars from the University of Florida (USA). Commercial production began in 1990 in Vacaria (RS). In Ceará, there is currently only one commercial producer, and no scientific or official production data exist to confirm local output. However, there is governmental encouragement and international interest in establishing production in the state (SERPA, 2022).

Blueberry marketing has expanded globally in recent years. According to Lima (2021), world production increased from 211,144 tons in 2017 to 596,813 tons in 2020. During the same period, the global planted area nearly doubled, from 54.8 thousand hectares to 109.5 thousand hectares. In Brazil, there are no official data on blueberry production; however, in 2017, 72.17 tons were marketed, with 13.4% from Rio Grande do Sul and 4% from Santa Catarina, and the remainder imported from Chile, the USA, Peru, and Argentina (Ceagep, 2022).

Cultivating blueberries in new regions like Ceará depends mainly on the availability of cultivars and cultivation systems adapted to local conditions. Although 20 genera of plants are commonly referred to as blueberries, commercial species are found in the *Vaccinium* genus (450 species) (Cantuarias-Avilés et al., 2014). Galletta & Ballington (1996) classify blueberries into five commercial groups: 1. Highbush; 2. Half high; 3. Southern Highbush; 4. Rabbiteye; and 5. Lowbush. Only Southern Highbush varieties, known as “no chill” types, are suitable for local cultivation since they do not require chilling temperatures (<7.2 °C) to produce (Antunes, 2005).

To stimulate blueberry production in Ceará, beyond identifying cultivars adapted to the state's climate, it is essential to develop cultivation systems tailored to local conditions that also reduce production costs. Therefore, this study aimed to evaluate the initial development and production of three cultivars (Biloxi, Biloxi XL, and Emerald) under the climatic conditions of the Baturité highlands.

Materials and Methods

The experiment was conducted in the municipality of Aratuba, Ceará, at Sítio Flexeiras, located at coordinates 4° 25' 04" S and 39° 02' 42" W, with an altitude of 778 meters. The cultivars used in the planting were Biloxi, Biloxi XL, and Emerald, all belonging to the “Southern Highbush” subgroup and described in the literature as tolerant to the absence of chilling (<7.2 °C). The blueberry seedlings were obtained from the Fruit Growing Sector Nursery of the University of Brasília.

The cultivation was carried out in a greenhouse covered with bird netting (white, 18%), since birds are considered pests that cause economic damage to plants, potentially leading to losses of up to 30% of fruits at the final ripening stage (Cantuarias-Avilés et al., 2014). Plants were grown in 30-liter pots filled with a substrate composed of 10 liters of well-decomposed cattle manure, 10 liters of crushed carnauba bagasse, and 10 liters of sandy soil. After transplanting, 2 liters of acidic peat (Carolina Soil®) were applied to each pot. The seedlings were transplanted to the field after a 30-day acclimatization period, with approximately 20 cm in length. Plant spacing was set at 1.5 m between rows and 0.5 m between plants within rows. The planting density was 13,333 plants per hectare. A total of 240 plants were cultivated, with 80 plants of each cultivar, arranged in 8 planting rows with 30 plants per row, in a randomized block design with four replicates. Data were collected from five plants per experimental plot.

The crop's nutritional requirements were met according to the recommendations by Lima (2021). Although the cultivation system used pots, fertigation—described by some authors as ideal for this crop—was not adopted. Instead, fertilization was performed by applying fertilizers directly into the pots in five installments, spaced 45 days apart, to meet the full nutritional demand of the crop cycle, as described by Lima (2021). Organic fertilizers used included ProtamimGR® (13% N), AlgenOceana® (32% Ca and 2% Mg), Fosfanatural.Agroadubo® (27% P₂O₅ and 32% Ca), and rock powder Rochamax® (3.9% K₂O and 1.5% S). Irrigation was done via drip system in six daily shifts (07:00, 09:00, 11:00, 13:00, 15:00, 17:00), applying a total of 2.5 liters of water per plant per day.

Morphological traits were evaluated based on bud development stages described by Childers & Lyrene (2006), considering the beginning of flowering (more than 5% of open flowers). The descriptors assessed were: main stem height (MSH), number of primary branches (NPB), and number of secondary branches (NSB). At harvest, the following traits were measured: number of fruits per plant (NFP), fresh fruit mass per plant (FFM), fruit longitudinal diameter (FD) in millimeters, total soluble solids content (°Brix) using a refractometer, and titratable acidity (TA). The variables FD, °Brix, and TA were measured on the same five plants used for morphological data collection. Average fruit yield per plant (AFP) and estimated yield per hectare (EYH) were calculated based on the planting density of 13,333 plants ha⁻¹ (1.5 m between rows and 0.5 m between plants), the number of fruits per plant (NFP), and the fresh fruit mass per plant (FFM).

Harvests were carried out every two days, with individual fruit weighing per plant. Fruits were harvested at full ripening stage, as described by Childers & Lyrene (2006), characterized by a violet color and the presence of bloom (a whitish wax coating on the fruit surface).

The experiment was conducted in a randomized block design (RBD), arranged as a 3×80 scheme (three cultivars and 80 plants per cultivar), with four replicates per treatment. For the collected data, residual normality was first tested. Subsequently, analysis of variance (ANOVA) was performed, and when significant, means were compared using Tukey's test at a 5% probability level. All statistical analyses were performed using GENES software, version 2022.24 (Cruz, 2013).

Results and Discussion

According to the mean test, the blueberry cultivars Emerald, Biloxi XL, and Biloxi show in **Table 1** the means obtained for the following parameters: main stem height (MSH), number of primary branches (NPB), and

number of secondary branches (NSB).

Regarding the main stem height (MSH3), the Emerald cultivar showed the highest mean value (52.80a), followed by Biloxi XL (44.70a) and Biloxi (35.30b). Different letters next to the means indicate significant differences among cultivars according to Tukey's test at a 5% probability level. This suggests that the Emerald cultivar exhibits greater vertical development compared to Biloxi, while Biloxi XL is intermediate and does not differ statistically from Emerald. Thus, main stem height is a relevant indicator of vegetative development of plants, as it directly reflects their production capacity and fruit quality (Pasa et al., 2014).

Following the expected development pattern for the species, a continuous increase in main stem height was observed in all cultivars throughout the experimental period. This vertical growth aligns with the characteristics of the Southern Highbush group, to which Emerald, Biloxi XL, and Biloxi belong, whose plants can reach about 2 meters in height, as described by Cantuarias-Avilés et al. (2014).

The traits number of primary branches (NPB) and number of secondary branches (NSB) did not show significant differences between the 'Biloxi' and 'Emerald' cultivars, indicating that under the experimental conditions, both varieties showed better means for this characteristic (Table 1). It is important to note that although results were not statistically significant, the 'Emerald' cultivar presented higher values for both parameters, indicating a tendency for greater branching capacity.

Regarding the means, significant statistical differences were observed only in main stem heights (MSH). However, these differences were recorded only in measurements MSH1 and MSH2 (Table 1). The other measurements did not show significant differences, indicating that in the field, cultivars exhibit similar vegetative development under the edaphoclimatic conditions of the Maciço de Baturité.

Concerning phenology, all cultivars went through the main developmental stages, including pre-flowering, beginning of flowering, full flowering, end of flowering,

fruit formation, color change, and fruit maturation under the edaphoclimatic conditions of the region. These stages are essential for characterizing the blueberry developmental cycle and provide important information about plant behavior relative to climate and soil (Antunes et al., 2008).

However, although both cultivars went through the same phenological stages, it is important to highlight that the 'Emerald' cultivar presented the best results in all these phases. This cultivar showed more efficient development, reaching the flowering and fruit maturation stages with greater consistency and precocity, which may indicate its better adaptation to the specific conditions of the region. Results found by Medina et al. (2018) showed the 'Emerald' cultivar peaking in lateral shoot growth due to high temperatures, where the emergence of lateral shoots allows an increase in the plant's productive potential.

According to the analysis of variance, a significant effect was found for the genotypes analyzed for the variables average fruit diameter per plot (AFDp), total number of fruits per plot (TNFp), total fruit weight per plot (TFWp), total soluble solids (TSS), total number of fruits per hectare (TNFh), and PROD – estimated production in kilograms per hectare at 1% and 5% significance levels (Table 2).

Regarding the main stem height (MSH3), the Emerald cultivar exhibited the highest mean value (52.80a), followed by Biloxi XL (44.70a) and Biloxi (35.30b). Different letters next to the means indicate significant differences among cultivars according to Tukey's test at a 5% probability level. This suggests that the Emerald cultivar shows greater vertical development compared to Biloxi, while Biloxi XL holds an intermediate position, not differing statistically from Emerald. Thus, main stem height is a relevant indicator of the vegetative development of plants, as it directly reflects production capacity and fruit quality (Pasa et al., 2014).

Following the expected developmental pattern for the species, a continuous increase in main stem height was observed in all cultivars evaluated throughout the experimental period. This vertical growth aligns with the

Table 1 – Mean values obtained for blueberry cultivars in the Maciço de Baturité.

Cultivars	Descriptor								
	AHP1	AHP2	AHP3	NRP1	NRP2	NRP3	NRS1	NRS2	NRS3
Emerald	41,25a	45,65a	52,80a	1,35a	2,2a	2,20a	3,70a	3,70a	3,70a
Biloxi XL	30,02b	37,05b	44,70a	1,20a	2,0a	2,0a	3,40a	3,50a	3,50a
Biloxi	21,02c	27,55c	35,30b	0,85a	1,90a	1,90a	3,00a	3,10a	3,10a

MSH – Main stem height; NPB – Number of primary branches; NSB – Number of secondary branches. Means followed by the same letter in the column do not differ significantly from each other at the 5% probability level according to Tukey's test

characteristics of the Southern Highbush group, to which Emerald, Biloxi XL, and Biloxi belong, whose plants can reach approximately 2 meters in height, as described by Cantuarias-Avilés et al. (2014).

The traits number of primary branches (NPB) and number of secondary branches (NSB) did not show significant differences between the 'Biloxi' and 'Emerald' cultivars, indicating that under the experimental conditions, both varieties presented similar mean values for this characteristic (Table 1). It is important to note that, although the results were not statistically significant, the 'Emerald' cultivar showed the highest values for both parameters, indicating a trend towards greater branching capacity.

Regarding the means, statistically significant differences were observed only for main stem heights (MSH). However, these differences were recorded only in measurements MSH1 and MSH2 (Table 1). The remaining measurements showed no significant differences, indicating that in the field, cultivars exhibit similar vegetative development under the edaphoclimatic conditions of the Maciço de Baturité.

Concerning phenology, all cultivars went through the main developmental stages, including pre-flowering, beginning of flowering, full flowering, end of flowering, fruit formation, color change, and fruit maturation, within the edaphoclimatic conditions of the region. These stages are essential for characterizing the blueberry developmental cycle and provide important information about plant behavior relative to climate and soil (Antunes et al., 2008).

However, although both cultivars went through the same phenological stages, it is important to emphasize that the 'Emerald' cultivar presented the best results in all these phases. This cultivar showed more efficient

development, reaching the flowering and fruit maturation stages with greater consistency and earliness, which may indicate its better adaptation to the specific conditions of the region. Results found by Medina et al. (2018) showed that the 'Emerald' cultivar exhibited a peak of lateral shoot emergence due to high temperatures, where this emergence of lateral shoots allows an increase in the plant's productive potential.

According to the analysis of variance, a significant effect was observed for the genotypes analyzed for the variables average fruit diameter per plot (AFDp), total number of fruits per plot (TNFp), total fruit weight per plot (TFWp), total soluble solids (TSS), total number of fruits per hectare (TNFh), and PROD – estimated production in kilograms per hectare at 1% and 5% significance levels (Table 3).

The higher altitude of Aratuba may have positively influenced the microclimate of the region, providing milder temperatures and better rainfall distribution, factors that contribute to more uniform fruit ripening and superior fruit quality. Additionally, the climatic differences presented in the city can impact other variables, especially those related to physiological processes essential for plant growth and production, such as photosynthesis and stomatal conductance, affecting water absorption and nutrient assimilation by plants (Ru et al., 2024).

The 'Biloxi' cultivar responds positively to the edaphoclimatic conditions of the Maciço de Baturité region. Therefore, the combination of the local climate, with its specific temperature and precipitation characteristics, provided an ideal environment for plant development.

Regarding productive aspects, 'Biloxi' achieved the best results in terms of fruit size and quantity. The

Table 2 – Summary of the analysis of variance for productive descriptors of blueberry cultivars evaluated in the Maciço de Baturité.

F.V	GL	Mean square					
		DMFp	NFTp	PTp	SST	NFh	PROD
Blocks	3	1,58	72,55	37,55	0,05	7085503,47	3,66
Genotypes	2	12,11**	4. 10 ^{5**}	86927,58*	2,73*	3,9. 10 ^{9**}	8487,28**
Residual	6	0,15	134,63	53,47	0,34	13148328,99	5,23
Mean		12,43	418,83	261,67	9,9	130885,42	81,77
CV%		3,19	2,77	2,79	5,97	2,77	2,8

FV – Source of variation; GL – Degrees of freedom; CV – Coefficient of variation (%); DMFp – Average fruit diameter per plot; NFTp – Total number of fruits per plot; PTp – Total fruit weight per plot; SST – Total soluble solids; NFh – Total number of fruits per hectare; PROD – Estimated production in kilograms per hectare.

Table 3 – Mean values obtained for productivity descriptors of blueberry cultivars in the Maciço de Baturité.

Cultivars	DMFp	NFTp	PTp	SST	NFh	PROD
Biloxi	14,42 a	784,00 a	407,00 a	10,62 a	245000 a	127,18 a
Biloxi XL	11, 60 b	250,25 b	265,75 b	10,07 a	78203 b	83,04 b
Emerald	11, 25 b	222,35 b	112,25 c	9,00 a	69453 c	35,08 c

AFDp – average fruit diameter per plot; TNFp – total number of fruits per plot; TFWp – total fruit weight per plot; TSS – total soluble solids; TNFh – total number of fruits per hectare; PROD – estimated production in kilograms per hectare. Means followed by the same letter in the column do not differ significantly at the 5% probability level according to Tukey's test.

'Biloxi' cultivar shows potential for blueberry cultivation in the Maciço de Baturité region, presenting itself as an excellent option for local producers, expanding opportunities for growing high-value fruits.

Edger et al. (2022), in their study on the historical perspective and future directions of research and genetic breeding of *Vaccinium*, highlight that advances in the development of superior cultivars require investments in new biotechnological tools. These cultivars must exhibit greater resilience to multiple stresses and produce fruits that meet diverse consumer preferences, both in terms of quality and health benefits.

Considering this perspective, it becomes essential to conduct further studies to identify the most appropriate cultivation system for the crop in the Northeastern region, with an emphasis on the Maciço de Baturité. These future analyses should consider a range of agronomic and environmental variables, such as management types adopted, irrigation practices, pest and disease control strategies, as well as the most efficient fertilization methods. Such investigations are fundamental to adapting the crop to local conditions and maximizing its productive and commercial potential.

Conclusion

The cv. Biloxi demonstrated greater rusticity in response to the climatic conditions of the Maciço de Baturité region and can be recommended for more in-depth studies on adaptation and stability. Alternative cultivation systems to fertigation require further research and, if not properly tested, may strongly contribute to the failure to achieve the maximum production capacity of the cultivars.

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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.

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