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Pruning type and timing affect agronomic performance of blueberry plants grown in central Brazil

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Abstract

Global blueberry production more than quadrupled between 2010 and 2022. One of the factors contributing to this production growth was the development of new cultivars with little or no chilling requirements, capable of thriving in tropical regions. Therefore, the objective of this study was to assess the growth and fruit yield of blueberry plants (Biloxi cultivar) subjected to different pruning types and timings in the Distrito Federal (DF), Central-West region of Brazil. The experiment was conducted in an open field, using a randomized complete block design with 3 replications and 10 plants per plot, totaling 480 plants. The plants were grown in pots using a fertigation system and were subjected to two types of pruning (severe pruning and regular pruning) in the different seasons of the year. The plants were evaluated for vegetative growth, fruit yield, number of fruits per plant, mean fruit weight, and fruit transverse and longitudinal diameters. The results showed that Biloxi blueberry can be grown under the climate conditions of the central region of Brazil, during the four seasons of the year, despite the tropical climate conditions and no occurrence of temperatures lower than 7.2 °C. Higher fruit yields were found when pruning was performed in winter or spring. Severe pruning resulted in higher fruit yields compared to regular pruning in winter. Summer and autumn pruning treatments reduced fruit yield; however, it is an alternative to extend the production window of this crop in Brazil.

Keywords: Biloxi, Chilling requirements, Cultural practices, Fruit yield, *Vaccinium corymbosum*

Introduction

Blueberry (*Vaccinium corymbosum*) production worldwide more than quadrupled between 2010 and 2022, increasing from 439,000 Mg in 2010 to 1,860,000 Mg in 2022 (FAO, 2023; IBO, 2023). The blueberry market in the United States reached US$ 2.8 billion in 2022, corresponding to a growth of more than 15% compared to 2020 (IBO, 2023).

Peru was the world's largest exporter of blueberries in 2019 (Escalante Yaulilahua et al., 2023). According to data from the Foreign Trade Secretariat of the Brazilian Ministry of Development, Industry, Commerce, and Services, Brazil's blueberry exports reached 980,400 Mg in 2022, generating US$ 955 million (SECEX, 2023). Peru's blueberry exports reached 292,584 Mg in 2022, generating US$ 1.242 billion (IBO, 2023), exceeding the total value of all fruit exports from Brazil. However, Peru's high blueberry exports indicate a profitable opportunity for fruit growers in Brazil.

Blueberry plants are traditionally grown in temperate climates. They were s introduced to Brazil in the 1980s, but were limited to Rio Grande do Sul, Santa Catarina, Paraná, São Paulo, and Minas Gerais, states located in regions with 300 to 1,200 chill hours per year. The estimated area cultivated with blueberries is approximately 400 hectares; however, there are no updated official data (Cantuarias-Avilés et al., 2014). The development of new cultivars with low chilling requirements has enabled the expansion of blueberry fields to regions of the country with less occurrence of low temperatures (Medina, 2016), such as the Distrito Federal (Federal District), in the Central-West region of Brazil.

Therefore, studies on temperate-climate crops have been conducted in tropical and semiarid regions using cultivars with low chilling requirements. In this sense, the Biloxi blueberry cultivar stands out among cultivars

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with these characteristics due to its early maturation and low chilling requirement, which is 150 to 400 chill hours per year to overcome dormancy (Retamales & Hancock, 2012). This is a vigorous shrubby cultivar with high fruit yield and one of the most important grown in Mexico and Peru (Retamales & Hancock, 2012; Rodríguez-Gálvez et al., 2020) due to its adaptation to the climate conditions of these countries. Moreover, blueberry plants respond differently to pruning types and timings (Lee et al., 2015; Muñoz et al., 2017; Strik & Buller, 2003), denoting the need for more studies on the effects of pruning on blueberry fields in Brazil.

Blueberry production is highly affected by the seasons of the year. Growing blueberry fields in Brazil is difficulty due to high mean annual temperatures. Therefore, investigating the fruit production of low-chill blueberry cultivars is important, focusing on different pruning types and timings, which can affect fruit production. In this context, the objective of this study was to assess the growth and fruit yield of blueberry plants (Biloxi cultivar) subjected to different pruning types and timings in Brasília, Distrito Federal, Brazil.

Material and methods

The experiment was conducted in an open field at the Fruit Production Sector of the Experimental Biology Station of the University of Brasília (EEB/UnB), Brasilia, Distrito Federal (DF), Brazil (15°44'11.9"S, 47°52'53.3"W, and altitude of 1,010 meters). The region's climate is classified as Aw, according to Köppen-Geiger classification, characterized by rainy summers (October to April) and dry winters (May to September) (Cardoso et al., 2014), with a mean annual temperature of 21.4 °C.

Blueberry seedlings were acquired from a certified commercial nursery in Nova Ponte, MG, Brazil. They were produced through micropropagation (in vitro) from explants of adult plants of the Biloxi cultivar to maintain genetic quality and seedling health. Subsequently, the seedlings were subjected to a 12-month acclimation period and then transplanted into 60-liter plastic pots containing rice husks as a substrate, where they were grown throughout the experiment. Pests and diseases were preventively controlled using chemical and biological pesticides.

Seedlings were Irrigated using a drip irrigation system consisting of a 3-hp motor pump, a 50 mm diameter main line, disc filters, 32 mm distribution lines, and 16 mm lateral lines with drippers operating in a flow rate of 8 liters hour^{-1}. Fertilizers were applied through fertigation using macro and micronutrients, according to the recommendations of Raseira & Antunes (2004) for growing blueberry plants.

Blueberry is sensitive to pH higher than 5.5, thus, pH was controlled between 4.5 and 5.5 through irrigation water using phosphoric acid (H_3PO_4). The electrical conductivity of the nutrient solution was also controlled, maintaining it between 0.8 and 1.0 dS m^{-1} (Voogt et al., 2014).

The experiment was conducted in a randomized complete block design with 3 replications and 10 plants per plot, totaling 480 plants. The spacing between plants was 1 × 0.4 m. Treatments were arranged in split-plot designs with pruning type and pruning timing as the factors.

Adult plants were subjected to two pruning types, following the methodology adapted from Muñoz et al. (2017): (1) severe pruning, consisted of removing lateral canes, and (2) regular pruning, characterized by maintaining lateral canes. Post-pruning, a copper-based paste was applied to prevent the entry of pathogens at the pruning wounds. The effect of pruning timing was analyzed for the four seasons (winter, spring, summer, and autumn). Therefore, each pruning treatment was implemented at four different times with 90-day intervals, totaling 8 treatments: August 21 (winter pruning), November 21 (spring pruning), February 21 (summer pruning), and May 21 (autumn pruning).

Severe pruning consisted of cutting all canes 15 cm above the plant crown. Regular pruning consisted of the same procedure, but maintaining one branch until new shoots emerged on the pruned canes (30 days after pruning), at which point it was cut.

The following vegetative and yield parameters were evaluated for each treatment over the first crop season: number of fruits, fruit production per plant (g plant^{-1}), estimated fruit yield (Mg ha^{-1}), mean fruit weight (g), fruit transverse and longitudinal diameters (mm), number of canes, plant height (cm), and stem diameter (mm) , at 30, 60, 90, and 120 days after pruning. These parameters were assessed using a measuring tape, a digital scale (Filizola), and a digital caliper (iGaging Absolute Origin).

Post-harvest analyses

Post-harvest analyses of blueberry fruits were conducted at the UnB Fruit Production Laboratory using the same experimental design as the field experiment. Fruits were harvested weekly at the complete maturity stage and then evaluated for fresh weight and transverse and longitudinal diameters.

Experimental stages

The dates and duration of each experimental stage (pruning, flowering, and harvest) are shown in **Tables 1** and **2.**

Statistical analysis

The obtained data were subjected to analysis of variance using the F-test, and significant means were compared using the Scott-Knott test, both at a 5% significance level. Statistical analyses and graph development were performed using Sisvar and GraphPad Prim 9 software, respectively.

Results and discussion

A total of 240 plants were analyzed during 18 months; each pruning type and timing combination was evaluated using 30 plants. All plants produced fruits and there was no severe contamination by pathogens or pest attack during the experiment.

A total of 87 hours below 12 °C and 601 hours below 15 °C were observed during the experiment (**Table 3**) indicating that the chilling requirements for Biloxi blueberry buds to overcome dormancy were met under tropical growing conditions. These results contradict those reported by Spiers et al. (2002) and Retamales &

Table 1. Dates of experimental stages for each pruning treatment

Pruning treatment	Pruning	Beginning of flowering	Beginning of harvest	End of harvest
Severe winter pruning	Aug 21, 2019	Dec 15, 2019 Mar 26, 2019	Feb 04, 2020 Jun 05, 2020	Mar 05, 2020 Dec 18, 2020
Regular winter pruning	Aug 21, 2019	Dec 15, 2019 Mar 26, 2020	Feb 04, 2020 Jun 05, 2020	Dec 18, 2020
Severe spring pruning	Nov 25, 2019	Mar 26, 2020	Jun 05, 2020	Dec 18, 2020
Regular spring pruning	Nov 25, 2019	Mar 26, 2020	Jun 05, 2020	Dec 18, 2020
Severe summer pruning	Feb 28, 2020	Jun 01, 2020	Aug 21, 2020	Dec 18, 2020
Regular summer pruning	Feb 28, 2020	May 25, 2020	Aug 14, 2020	Dec 18, 2020
Severe autumn pruning	May 21, 2020	Jul 31, 2020	Nov 10, 2020	Feb 26, 2021
Regular autumn pruning	May 21, 2020	Jul 24, 2020	Nov 10, 2020	Feb 26, 2021

Table 2. Duration (weeks) of flowering, harvest, and pruning to harvest in each treatment.

Treatment	Flowering	Harvest	Pruning to harvest
Severe winter pruning	7 / 10	4 / 28	24
Regular winter pruning	7 / 10	4 / 28	24
Severe spring pruning	10	28	28
Regular spring pruning	10	28	28
Severe summer pruning	12	17	24
Regular summer pruning	12	18	25
Severe autumn pruning	13	15	25
Regular autumn pruning	13	15	25

Table 3. Meteorological data recorded during the experimental period (August 2019 to February 2021), in Brasília, DF, Brazil, according to INMET (2023): Monthly mean (Tmean), maximum (Tmax), and minimum (Tmin) temperatures and monthly number of chill hours below 18 °C (CH < 18), 15 °C (HF < 15), 12 °C (CH < 12), 10 °C (CH < 10), and 7.2 °C (CH < 7.2).

Month	Tmean	Tmax	Tmin	CH < 18	CH < 15	CH < 12	CH < 10	CH < 7.2
	°C			h				
Aug-19	21.4	28.1	15.4	208	51	0	0	0
Sep-19	24.6	31.4	18.5	46	0	0	0	0
Oct-19	24.6	31.3	19.2	26	0	0	0	0
Nov-19	23.2	29.3	18.8	44	0	0	0	0
Dec-19	22.8	28.3	19.0	16	0	0	0	0
Jan-20	22.6	27.6	19.1	14	0	0	0	0
Feb-20	22.1	27.3	18.8	48	0	0	0	0
Mar-20	21.9	27.0	18.6	26	0	0	0	0
Apr-20	21.4	26.7	18.0	65	6	0	0	0
May-20	19.4	25.5	14.5	339	110	30	14	0
Jun-20	19.3	25.6	13.8	342	156	23	1	0
Jul-20	19.3	25.7	13.4	355	148	20	0	0
Aug-20	20.8	27.1	14.4	287	118	14	3	0
Sep-20	23.4	29.8	17.3	97	8	0	0	0
Oct-20	23.8	29.7	19.3	28	0	0	0	0
Nov-20	21.9	27.2	18.1	88	2	0	0	0
Dec-20	22.8	28.4	18.6	49	0	0	0	0
Jan-21	22.4	28.2	18.1	108	1	0	0	0
Feb-21	21.1	26.3	18.4	95	1	0	0	0
Total	-	-	-	2281	601	87	18	0

Hancock (2012), who stated that Biloxi blueberry plants require 150 to 400 hours below 7.2 °C to break dormancy.

The number of fruits, fruit production per plant, and estimated fruit yield at the end of the experiment varied according to the pruning type and timing. The number of fruits per plant (NFP) was higher for severe winter pruning (**Figure 1**A), but with no significant differences between severe and regular pruning in the other seasons of the year. The highest NFP were found for winter pruning, followed by spring, autumn, and summer pruning. Severe winter pruning resulted in an increase of 317% in NFP compared to severe summer pruning. Regular winter pruning resulted in an increase of 190% in NFP compared to the regular summer pruning.

Fruit production per plant (FPP) was significantly different between pruning types in winter and spring (Figure 1B), denoting a significant effect of pruning timing and type. Severe pruning in winter or spring resulted in higher FPP compared to regular pruning (Figure 1B).

FPP showed no significant difference between pruning types in summer and autumn (Figure 1B); however, it varied significantly among pruning timings. Severe winter pruning resulted in the highest FPP, followed by severe pruning in spring, autumn, and summer. Regarding regular pruning, FPP did not differ significantly between winter and spring, but showed significantly higher means compared to autumn and summer pruning.

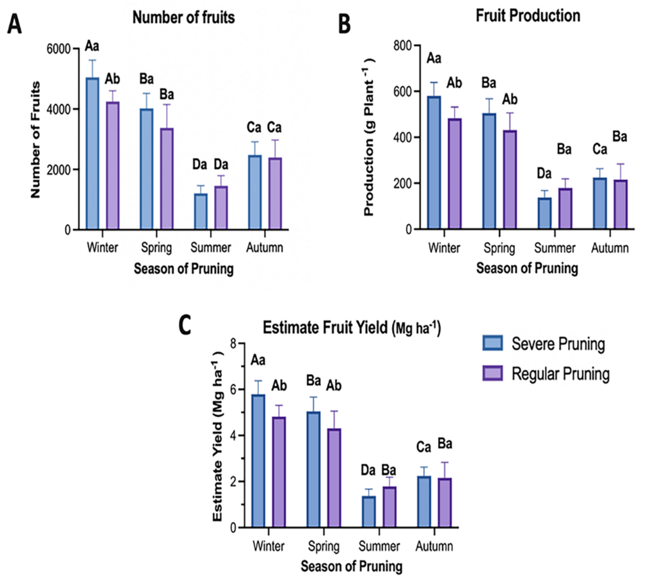
Fruit yield (Mg ha^{-1}) estimated based on the mean plant density for the Biloxi blueberry cultivar (25,000 plants ha^{-1}), significantly differed between pruning types in winter and spring (Figure 1C). Severe winter pruning resulted in a fruit yield of 14.5 Mg ha^{-1}, whereas regular winter pruning resulted in 12.06 Mg ha^{-1}. For severe pruning, fruit yield was significantly lower for summer compared to the other seasons.

The analysis of severe pruning formed 3 groups for pruning timings (seasons) within pruning types, and two groups for pruning types within seasons. Severe pruning in winter resulted in the highest fruit yield (14.50 Mg ha^{-1}) followed by spring (12.64 Mg ha^{-1}), autumn (5.63 Mg ha^{-1}), and summer (3.46 Mg ha^{-1}), which was 319% lower than that found for winter. The analysis of regular pruning formed 2 groups within seasons, with the highest fruit yield found for winter (12.06 Mg ha^{-1}) and spring pruning (10.78 Mg ha^{-1}), followed by autumn (5.41 Mg ha^{-1}) and summer pruning (4.49 Mg ha^{-1}). The highest mean fruit yield (winter pruning) was 168% higher than the lowest mean (summer pruning). These results show that pruning timing affects fruit yield.

Mean fruit weight (MFW) is an important characteristic for blueberry growers as a high MFW signifies high harvest efficiency. Harvesting heavier blueberries is faster, therefore, fewer fruits are needed to fill a commercial blueberry packaging.

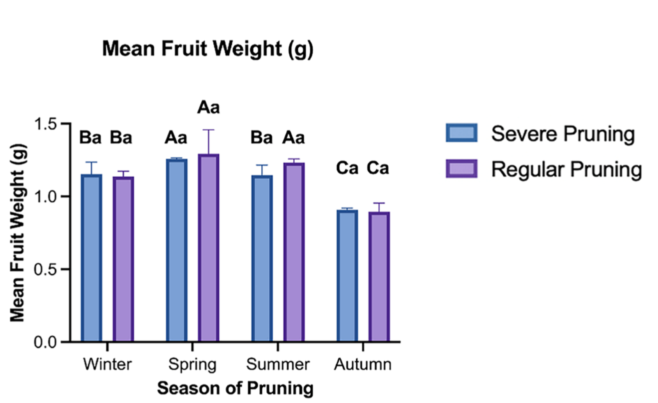
MFW did not differ significantly between pruning types within pruning timings (**Figure 2**). However, the effect of pruning timing was significant on MFW, forming 3 groups for the two pruning types. Spring and pruning autumn resulted in the highest and lowest MFW values, respectively; for spring, MFW was 44% (regular pruning) and 38% (severe pruning) higher compared to those found for in autumn.

Fruit transverse diameter (FTD) is one of the most important factors influencing consumer choice, as it represents the fruit's largest dimension. This parameter showed minimal variation (**Figure 3**A). Pruning type within



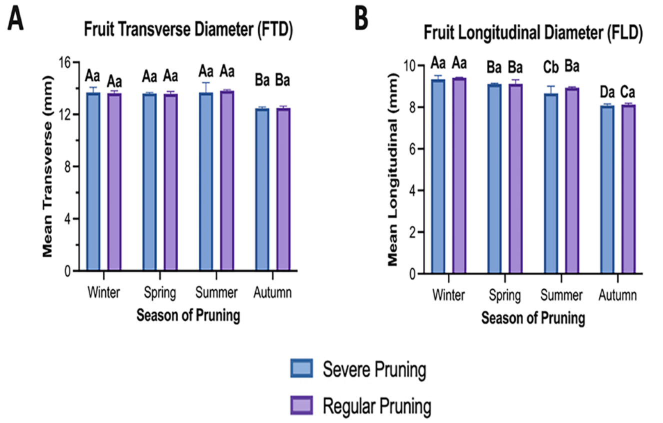
Bars with different uppercase letter comparing pruning timings or lowercase letter comparing pruning types are significantly different from each other by the Scott-Knott test at a 5% significance level.

Figure 1. Number of fruits (A), fruit production (g $plant^{-1}$) (B), and estimated fruit yield (Mg ha^{-1}) (C) as a function of different pruning types and timings for Biloxi blueberry plants.



Bars with different uppercase letter comparing pruning timings or lowercase letter comparing pruning types are significantly different from each other by the Scott-Knott test at a 5% significance level.

Figure 2. Mean fruit weight as a function of different pruning types and timings for Biloxi blueberry plants.



Bars with different uppercase letter comparing pruning timings or lowercase letter comparing pruning types are significantly different from each other by the Scott-Knott test at a 5% significance level.

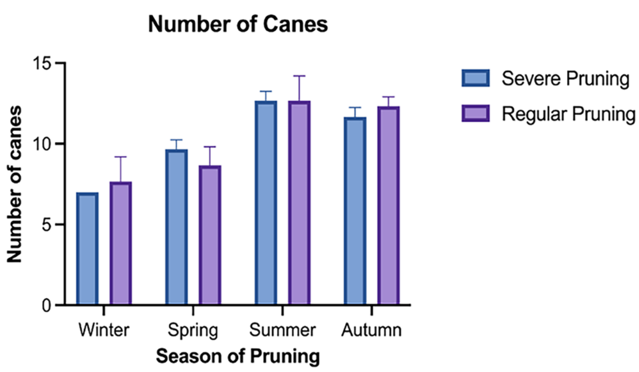
Figure 3. Mean transverse (A) and longitudinal (B) diameters of fruits from Biloxi blueberry plants as a function of different pruning types and timings.

pruning timings had no significant effect on FTD; similar result was found for pruning timing within pruning types. Autumn pruning resulted in a slightly lower FTD compared to the other pruning timings, but with no statistically significant difference (Figure 3A). Therefore, pruning type and timing had no significant effect on FTD.

Fruit longitudinal diameter (FLD) showed significant difference between pruning types only for summer pruning (Figure 3B). Severe pruning in winter resulted in the largest FLD, followed by spring, summer, and autumn. Regular pruning analysis formed 3 groups, with regular spring and summer pruning resulting in similar FLD values; winter pruning resulted in the smallest, and autumn pruning in the largest FLD among seasons.

The comparison of severe and regular pruning within each season revealed no significant difference in the number of canes (**Figure 4**).

Pruning type had no significant effect on the number of canes emerged during the crop cycle. However, pruning timing had significant effect on this variable, as autumn and summer pruning resulted in

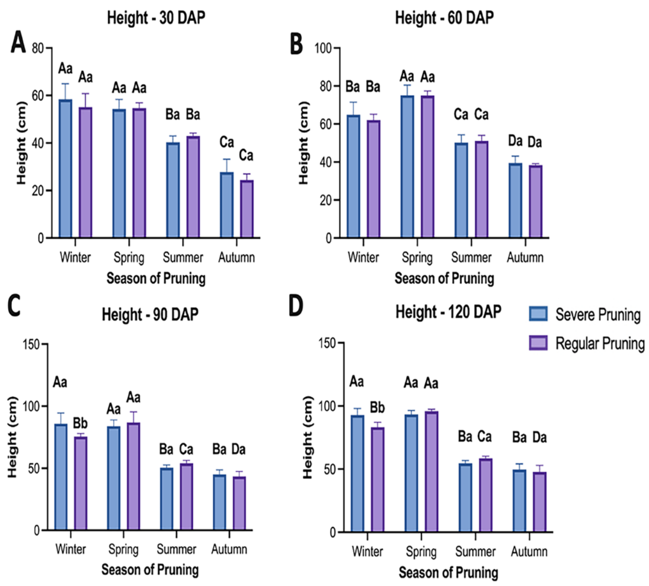


Bars with different uppercase letter comparing pruning timings or lowercase letter comparing pruning types are significantly different from each other by the Scott-Knott test at 5% probability level.

Figure 4. Number of canes of Biloxi blueberry plants as a function of pruning types and timings

higher numbers of canes, followed by spring and winter pruning. Pruning type had no significant effect on plant height (**Figure 5**A-E), which showed similar means within pruning timings.

Plant height was affected by pruning timing. Winter and spring pruning resulted in higher plant heights than summer and autumn pruning (Figure 5). Winter and spring pruning resulted in plants nearly twice as tall as those pruned in the other seasons. Plants pruned in summer and autumn had an earlier growth stagnation (Figure 6C and 6D) than in winter- or spring-pruned plants (Figure 6A and 6B).



Bars with different uppercase letter comparing pruning timings or lowercase letter comparing pruning types, are significantly different from each other by the Scott-Knott test at a 5% significance level.

Figure 5. Plant height for Biloxi blueberry plants as a function of pruning types and timings, assessed at 30 (A), 60 (B), 90 (C), and 120 (D) days after pruning.

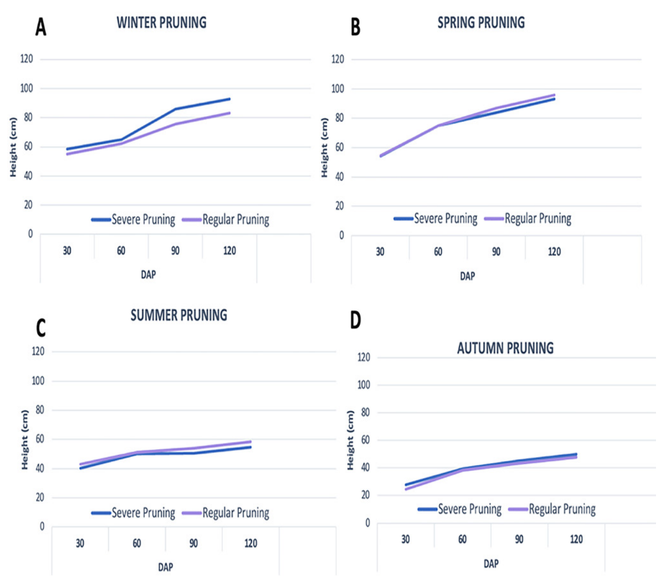


Figure 6. Growth curve after pruning in winter (A), spring (B), summer (C), and autumn (D) for Biloxi blueberry plants.

Pruning type had no significant effect on stem diameter of blueberry plants).

However, pruning timing had significant effect on stem diameter. Winter and spring pruning resulted in plants with larger stems than summer and autumn pruning (**Figure 7**).

The blueberry production in Brazil is limited and concentrated in regions with higher number of chill hours. However, the current development of new blueberry cultivars that require fewer chill hours to produce fruits have generated the possibility of producing these fruits in the entire country. However, there is little recent data on production and dynamics of blueberry plants in Brazilian regions with milder winters (average minimum temperatures higher than 7.2 °C).

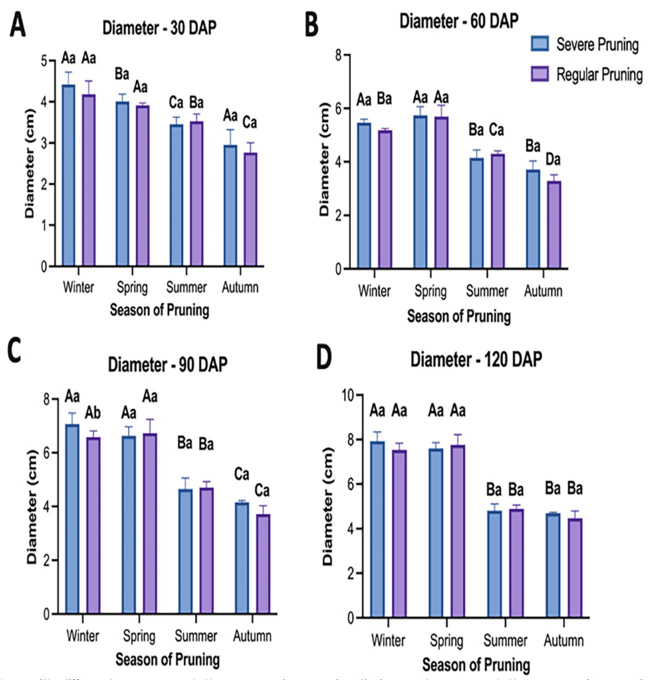
In this sense, this evaluation of the correlation between pruning timings and the development and production of Biloxi blueberry plants under the climate conditions of Distrito Federal, Central-West region of Brazil, showed that severe pruning in winter resulted in the highest fruit yield (5.8 Mg ha^{-1}) followed by spring (5.05 Mg ha^{-1}), autumn (2.25 Mg ha^{-1}), and summer (1.38 Mg ha^{-1}), despite the lack of temperatures below 7.2 °C during the experimental period. These results show that pruning blueberry plants between August and February results in higher fruit yield compared to pruning in other months.

The estimated fruit yields varied from 3.46 to 14.50 Mg ha^{-1} (based on a plant density of 25,000 plants ha^{-1}) depending on the pruning timing. Cortés-Rojas et al. (2016) evaluated blueberry cultivars in Guasca, Colombia, and the lowest fruit yield (4.127 Mg ha^{-1}) was found for 20-month-old Biloxi blueberry plants grown at a density of 5,600 plants ha^{-1} under an average temperature of 12.9 °C. Robledo et al. (2020) evaluated the agronomic performance of 12-month-old Biloxi blueberry plants grown in two locations in Peru (mean temperatures of 15.8 and 14.6 °C, respectively) at a density of 6,666 plants ha^{-1} and found lower fruit yields (1.44 and 1.66 Mg ha^{-1}) than those obtained in the present study. These results denote that Biloxi blueberry plants can be grown in Brazil with fruit yields similar to or higher than those found in other countries with colder climates.

The highest fruit yield found for severe winter pruning was 5.8 Mg ha^{-1}, whereas the highest fruit yield found for regular winter pruning was 4.83 Mg ha^{-1}. This result can be attributed to greater heights and stem diameters of plants pruned in winter. Winter and spring pruning resulted in greater plant heights than summer and autumn pruning. The highest plant heights at 120 days after pruning were not significantly different from each other: 95.85 cm (spring regular pruning) and 92.77 cm (severe winter pruning). However, summer and autumn pruning resulted in the lowest plant heights at 120 days after pruning: 54.61 cm (severe summer pruning) and 47.84 cm (regular autumn pruning).

Segantini et al. (2014) also found lower fruit yield for autumn pruning compared to winter pruning for blackberry plants (cultivar Tupy) grown in São Manuel, SP, Brazil. Contrastingly, Kovaleski et al., 2015) found no effect of pruning timing on fruit yield and mean fruit weight for blueberry plants of the cultivar Emerald. The highest fruit yield found for winter pruning can be attributed to the greater heights and stem diameters of plants pruned in winter. Similarly, Palm & Retamales, 2017 found that plants with larger branch diameters resulted in higher fruit yield. Additionally, Xu et al. (2014) found positive correlation between plant height and fruit yield. Therefore, the combination of a longer harvest period and taller plants with larger stems resulted in a higher fruit yield for winter- and spring-pruned plants.

Fruit yield differed significantly between severe and regular pruning at the different seasons of the year. Severe pruning consists of eliminating all canes by cutting them 15 cm above the plant crown, whereas regular pruning involves the same procedure, but maintaining one branch, which is a common practice for pruning coffee plants (Matiello et al., 2016). Hoza et al. (2019) evaluated four blueberry cultivars (Duke, Draper, Patriot,



Bars with different uppercase letter comparing pruning timings or lowercase letter comparing pruning types are significantly different from each other by the Scott-Knott test at a 5% significance level.

Figure 7. Stem diameter of blueberry plants as a function of pruning types and timings, assessed at 30 (A), 60 (B), 90 (C), and 120 (D) days after pruning.

and Brigitta) and found that a more severe pruning resulted in higher fruit yields than a less severe one. Therefore, severe pruning may be a better alternative for pruning Biloxi blueberry shrubs grown in tropical-climate regions. However, the results of the present study are not sufficient to explain the highest fruit yield obtained by using severe pruning, and further studies are needed to demonstrate the effects of these pruning types on the physiology and fruit yield of blueberry plants.

Mean fruit transverse diameters varied from 12.47 mm (autumn) to 13.69 mm (winter) for severe pruning treatments; and from 12.50 mm (autumn) to 13.82 mm (summer) for regular pruning treatments. The statistical analyses showed no strong effect of pruning types and timings on fruit transverse diameter. Cuts-Rojas et al. (2016) evaluated the growth of Biloxi blueberry plants with 20 and 36 months of age and found mean diameters of 15 and 14 mm, respectively. These results were higher than those found in the present work, which still are within the means reported in other studies with the same cultivar (Frías-Ortega et al., 2020; Nagasaka et al., 2021). The results obtained in the present work shows that blueberries grown under the climate conditions of Distrito Federal, Central-West region of Brazil, have similar physical attributes to those grown in other regions of the world.

Conclusions

Biloxi blueberry plants can be grown under the tropical climate conditions of Distrito Federal, Brazil, throughout the four seasons of the year, despite the no occurrence of temperatures lower than 7.2 °C. Fruit yield is higher in plants pruned in winter or spring. Severe pruning results in higher fruit yield due to taller plants compared to regular pruning, although this difference was found only for winter pruning. Pruning blueberry plants during summer and autumn decreases fruit yield, but expands the crop production window. Fruit growers can invest in blueberry production under tropical climate conditions and practice winter or spring pruning to improve the agronomic performance of Biloxi blueberry plants in Brazil.

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