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Phenological and yield performance of black and redberry cultivars in western Paraná State

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ABSTRACT. Because grain cultivation in Paraná is becoming unsustainable on small farms, growing fruit should be explored on these production units. Thus, the objective of the present work was to quantify the phenology and production of cultivars of black and redberry plants in the western region of Paraná in the town of Marechal Cândido Rondon, Paraná State, Brazil. The experimental design was in randomized blocks, with four blocks and eleven treatments (blackberry cultivars Arapaho, Xavante, Ébano, Comanche, Caingangue, Choctaw, Tupy, Guarani, Brazos and Cherokee and the redberry plants). In each plot, composed of five plants, the phenological and production data for the 2009/10 and 2010/11 production cycles were collected, and the physicochemical quantification of the fruits in the last production cycle was performed. Most of the cultivars presented production cycles longer than 90 days, with the harvest beginning in late October and extending through late January. 'Brazos' presented the highest estimated yield. The Brazos, Guarani and Tupy cultivars produced fruits of higher masses. The redberry presented a high fruit yield and proved an excellent option for cultivation in this region.

Keywords: *Rubus* spp., *Rubus rosifolius*, phenology, fruit quality.

Fenologia e desempenho produtivo de cultivares de amoreiras-pretas e vermelha no Oeste paranaense

RESUMO. O cultivo de grãos no Paraná vem se tornando inviável em pequenas propriedades rurais. A fruticultura poderia viabilizar a exploração econômica nessas unidades produtivas. Assim, o objetivo do presente trabalho foi quantificar a produção de cultivares de amoreiras-pretas e vermelha na região Oeste do Estado do Paraná. O trabalho foi realizado no município de Marechal Cândido Rondon, Estado do Paraná. O delineamento experimental foi em blocos ao acaso, com quatro blocos e onze tratamentos (cultivares de amoreiras-pretas Arapaho, Xavante, Ébano, Comanche, Caingangue, Choctaw, Tupy, Guarani, Brazos, Cherokee e a amoreira-vermelha). Em cada parcela, constituída de cinco plantas úteis, foram coletados dados fenológicos e produtivos no ciclo de produção 2009/10 e 2010/11, além da quantificação físico-química dos frutos no último ciclo de produção. A maioria das cultivares apresentou ciclo produtivo superior a 90 dias, com colheitas se iniciando ao final de outubro e se estendendo até final de janeiro. 'Brazos' apresentou a maior produtividade estimada. As cultivares Brazos, Guarani e Tupy possibilitaram a produção de frutos de maior massa. A amoreira-vermelha apresentou elevada produção de frutos e poderia ser indicada como opção para o processamento.

Palavras-chave: *Rubus* spp., *Rubus rosifolius*, fenologia, qualidade de frutos.

Introduction

The western region of the state of Paraná is known for the intensive farming of grains, such as soybean, corn and wheat, occupying the largest portion of cultivated land and, therefore, constituting the basis of the economy of this region. However, phytosanitary problems associated with monocultures, increased production costs and reduced profitability have made the cultivation of these crops unviable on small farms (FURLANETTO et al., 2010). An option for these farmers would be to grow fruit as an alternative to grains, which could lead to improved profitability in western Paraná. Some studies have already demonstrated the potential exploitation of the fig tree (CAMPAGNOLO et al., 2010; DALASTRA et al., 2009) and grape vine (SILVA et al., 2010; WERLE et al., 2008).

The expansion of fruit growing in this region would also include the cultivation of the blackberry tree (*Rubus* spp.), which has the advantage that the establishment and maintenance cost of the orchards is relatively low when compared with other perennial fruit-bearing trees already under cultivation, offering income that is not based on household farming in western Paraná (ATTILIO et al., 2009). Indeed, the cultivation of Rubus species in Brazil is promising (ANTUNES et al., 2010).

The interest in blackberries has increased in recent years due, in part, to the high concentrations of phenolic and carotenoid compounds, which can help to protect against degenerative diseases (FERREIRA et al., 2010; JACQUES et al., 2010). In addition, several other natural pigments, mainly anthocyanin, are used in the making of dairy products, jams and preserves (ANTUNES, 2002).

Being a deciduous fruit-bearing tree of temperate climates, the main blackberry producing regions lie in Rio Grande do Sul State, Brazil. Nevertheless, new orchards have been established in subtropical regions, such as Caldas, Minas Gerais State, Brazil, and around the higher elevations of Minas Gerais and São Paulo Mantiqueira.

Antunes et al. (2006) conducted a trial of blackberry cultivation in Caldas, Minas Gerais State, and found that some cultivars presented an excellent yield performance, with fruit production higher than 'Tupy', Brazil's and Paraná State main cultivar Campagnolo and Pio (2012b). As each cultivar is unique with regard to the temperature requirements, differences in the performances of cultivars in different growing regions can occur. Therefore, the evaluation of other potentially higher-yielding cultivars is a highly important factor in the expansion of berry crops in the western region of western region of Paraná state.

The objective of the present work was to quantify the phenology and yield of black and redberry cultivars in the western region of Paraná State.

Material and methods

The experiment was conducted in the town of Marechal Cândido Rondon, Paraná State, Brazil, situated at 472 m of elevation, 24º35'42" latitude South and 53º59'54" longitude West. According to the climate classification, the region possesses a Cfa climate – a humid subtropical zone, with rainforest and annual maximum and minimum average temperatures of 28.5 and 16.6ºC, respectively. The soil in the experimental area is Eutroferric Red Latosol.

The seedlings of blackberry cultivars, thornless 'Arapaho', 'Xavante' and 'Ébano' and thorned 'Comanche', 'Caingangue', 'Choctaw', 'Tupy', 'Guarani', 'Brazos', and 'Cherokee', and redberry (*Rubus rosifolius*), species native to the Mantiqueira range, were grown according to the methodology by Villa et al. (2003) and Campagnolo and Pio (2012a). Seedlings were planted in the field in November of 2008 at a spacing of 3.0 x 0.5 m (a stand of 6,667 plants per hectare), and the plants were trained under single trellises of one thread in a "T" (parallel double threads), spaced 60 cm apart and 80 cm from the soil.

The experiment was conducted in randomized blocks containing 11 treatments (cultivars), with four blocks and five plants per experimental unit. The trees were cultivated according to the recommendations of Campagnolo and Pio (2012b). At each pruning, five liters of farmyard manure were distributed per linear meter in the direction of the wire threads. Four weedings of spontaneous plants were performed in the experimental area in the months of June, September and November of 2009 and 2010. In addition to the applications of farmyard manure (three liters per linear meter), single applications were performed in October and in December for each evaluation cycle.

In the production cycle of 2009/10 and 2010/11, the phenological stages (early budbreak, and duration of blooming and harvest) were evaluated from after the pruning, on April the first for the redberry plants and July the fifth for the blackberry cultivars, until the end of the harvest. The yield variables, number of fruits per plant, fresh mass of fruits (g), yield (g per plant) and estimated yield (kg ha^{-1}), in the two production cycles were evaluated from April to January. The fruits collected at each harvest, every three days, were counted and weighted with the aid of a digital semi-analytical scale. At the end of the production cycle, all of the values recorded for the determination of the yield per plant were summed, and the estimated yield was calculated by multiplying the yield by the population density (6,667 plants per hectare). The maximum and minimum average temperatures and accumulated rainfall for the months of April of 2009 to January of 2011 (Figure 1) were recorded.

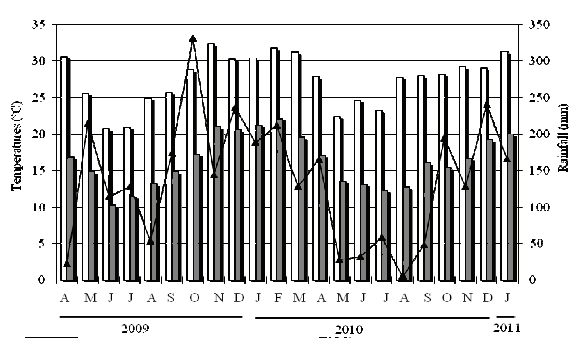

Figure 1. Maximum and minimum temperatures and accumulated rainfall (mm) for the months of April of 2009 to January of 2011 in the town of Marechal Cândido Rondon, Paraná State, Brazil. Marechal Cândido Rondon, Paraná State, Unioeste, 2011.

During the second harvest for each cultivar, in the month of December of 2010, 20 fruits per block were collected for the determination of the physical variables (length and average diameter of the fruits, with the aid of a digital pachymeter) and chemical variables, including the total titratable acidity (obtained through the titration of the samples with 0.1 Mol L^{-1} solutions of NaOH and expressed as a percentage of citric acid), total soluble solids (with the aid of a portable refractometer [ATAGO, model PAL^{-1}], at a temperature of 20ºC, with the reading expressed in ºBrix and the ratio of soluble solids and acidity.

The data were submitted to an analysis of variance, and the means were compared using the Scott-Knott test at a 5% of probability of error. The SISVAR (System for Variance Analysis- SISVAR) program was utilized for the statistical analysis.

Results and discussion

With regard to the early budbreak of the blackberry plants in the first production cycle (2009/10), the Comanche cultivar was the first to enter the budbreak stage. 'Cherokee', 'Brazos', 'Guarani' and 'Choctaw' initiated the budbreak stage in the second fortnight of August, and the others began in the first fortnight of September (Table 1). However, during the second production cycle, all cultivars initiated budbreak during the second fortnight of August, with the exception of 'Brazos' for which the budbreaking began nine days before the other cultivars. It is believed that, in the first year when the plants were younger, motive that caused the difference in the beginning of the budbreaks of the stems relative to the second production year. These results are important from the standpoint of the distribution of the blackberry plants in locations with climatic conditions similar to western Paraná State (Cfa – humid subtropical zone), but without the incidence of frost from the second fortnight of August and thereafter, which could cause decreased yield due to the injury caused to the new leaves.

It was found that blooming of the blackberry plants began in September in both of the production cycles, with the exception of the Brazos and Arapaho cultivars (Table 1). The duration of blooming in the second production cycle was longer, as the plants were more mature, an observation in agreement with the results of Antunes et al. (2000), who also found that the duration of blooming in young plants is shorter. The duration of blooming in the Ébano cultivar was shorter in relation to the others during both of the production cycles. The same trend occurred with the harvest duration, which was only 38 days during the second production cycle and 52 days during the second cycle. In addition, that cultivar was the latest, with harvests concentrated between December and January, in accordance with the results of Antunes et al. (2000) in Caldas, Minas Gerais State, Brazil (Cwa climate – humid subtropical zone). However, the harvest of the fruits of the other cultivars began during the second fortnight of October and lasted until the second fortnight of January, with the Brazos cultivar presenting the longest harvest duration in both of the production cycles.

Table 1. Phenological description of the production cycles 2009/10 and 2010/11 – early budbreak (EB), start, finish and duration of the blooming (BS, BF and DB) and harvest (SH, FH and DH) of plants of berries cultivars in Western Paraná, Brazil. Marechal Cândido Rondon, Paraná State, Unioeste, 2011.

Cultivar	EB	BS	BF	DB (days)	SH	FH	DH (days)
	Production cycle 2009/10						
Amora-vermelha	15/04	08/05	28/10	173	23/06	01/12	161
Xavante	15/09	22/09	10/12	79	18/11	07/01	50
Tupy	12/09	29/09	02/01	95	26/11	26/01	61
Caingangue	04/09	20/09	02/01	104	26/11	29/01	64
Comanche	03/08	06/09	21/12	106	30/10	18/01	80
Cherokee	29/08	07/09	18/12	102	24/10	18/01	86
Brazos	18/08	07/09	20/11	74	15/10	24/12	101
Arapaho	04/09	11/09	10/12	90	06/11	09/01	64
Guarani	16/08	18/09	05/12	78	06/11	02/01	57
Ébano	14/09	03/11	03/01	61	19/12	26/01	38
Choctaw	25/08	02/10	06/12	65	29/11	04/01	42
	Production cycle 2010/11						
Amora-vermelha	10/03	25/03	28/11	248	10/05	10/01	245
Xavante	19/08	10/09	09/01	122	01/11	10/01	70
Tupy	21/08	15/09	08/01	116	01/11	24/01	84
Caingangue	20/08	01/09	08/01	130	18/10	24/01	98
Comanche	19/08	01/09	08/01	130	23/10	19/01	88
Cherokee	22/08	01/09	07/01	135	26/10	18/01	84
Brazos	10/08	18/08	08/01	143	16/10	24/01	100
Arapaho	19/08	24/08	07/01	138	26/10	12/01	90
Guarani	19/08	01/09	06/01	128	28/10	08/01	84
Ébano	19/08	06/10	12/01	98	03/12	24/01	52
Choctaw	20/08	04/09	09/01	128	25/10	08/01	87

Regarding the performance of the yield of the blackberry cultivars, the greatest fruit yield in the first production cycle was recorded for 'Brazos' (194 fruits). In spite of the Tupy and Guarani cultivars having produced fruits of larger thickness, equal to 'Brazos', the number of fruits were not sufficient to amount to the yield of 7,523.8 kg ha^{-1} recorded for 'Brazos' (Table 2). However, for the second production cycle, the Brazos and Guarani cultivars bore increased number of fruits (493 and 476, respectively), and these two cultivars, along with 'Tupy', bore fruits with the largest thicknesses (larger than five grams). Consequently, the highest yield per plant occurred for the Guarani and Brazos cultivars, but, due to the number of fruits and slightly superior thickness, the greatest yield was found for 'Brazos' (18.602.5 kg ha^{-1}), followed by 'Guarani' (15.129.8 kg ha^{-1}) and then 'Tupy', 'Comanche' and 'Arapaho', but with yields of approximately 50% in relation to that obtained for 'Brazos'.

The results obtained in the present work corroborate the findings of Antunes et al. (2000) who also recorded increased yield with the Brazos cultivar, followed by Guarani, in Caldas, Minas Gerais State, Brazil. Differences were recorded with regard to the yield of the blackberry cultivars lacking thorns. In the present work, yields of 926.3 kg ha^{-1} in the first cycle and 1,427.2 kg ha^{-1} in the second cycle were recorded for the Ébano cultivar. In contrast, in a study conducted in Jundiaí, São Paulo State , Brazil (Cwa climate, mesothermal with dry winter, commonly named altitude tropical, according to Köppen classification), Martins and Pedro Junior (1999) recorded yields of 1,720 kg ha^{-1} in the first cycle and 2,893 kg ha^{-1} in the second cycle for the Ébano cultivar. Broetto et al. (2009) recorded a yield of 3,026 kg ha^{-1} in the first cycle using the Xavante cultivar at Guarapuava Paraná State, Brazil (Cfb climate, mesothermal with rainy winter); in the present study, we only recorded 62.2 kg ha^{-1} in the first cycle and 1,274.7 kg ha^{-1} in the second cycle. These differences may be related to the thermal requirements of each cultivar.

The greatest sizes (length and diameter) of fruits were reported for 'Brazos', followed by 'Guarani' and 'Tupy' (Table 3). These results were expected, as the fruits of those cultivars exhibited the greater masses (Table 2). The fruits of the Tupy and Caingangue cultivars presented lower acidity, whereas the fruits of the other cultivars proved to be more acidic, with the exception of the fruits of the Arapaho cultivar, which were of an intermediary classification (Table 3). As to the soluble solid contents, the fruits of the Tupy, Caingangue, Cherokee, Arapaho, Guarani and Choctaw cultivars recorded higher rates; however, due to the acidity of the fruits, the highest ratio between the concentration of total soluble solids and acidity were obtained for the Tupy and Caingangue cultivars (Table 3), suggesting palatability for fresh consumption.

Table 2. Average number of fruits, average fresh mass, production and estimated yield of the production cycles 2009/10 and 2010/11 of plants of berries cultivars in Western Paraná, Brazil. Marechal Cândido Rondon, Paraná State, Unioeste, 2011.

Cultivar	Number of fruits	Fresh mass (g)	Production (g)	Estimated yield (kg ha^{-1}) (2)
	Production cycle 2009/10 (1)			
Amora-vermelha	366.9 a	1.6 f	582.9 b	3,887.9 b
Xavante	4.7 f	2.0 e	9.4 f	62.2 f
Tupy	24.0 e	5.3 a	136.7 d	911.6 d
Caingangue	42.0 d	3.4 c	144.9 d	966.3 d
Comanche	77.6 c	3.5 c	277.6 c	1,851.7 c
Cherokee	23.3 e	2.5 d	60.6 e	404.3 e
Brazos	194.2 b	5.8 a	1,128.1 a	7,523.8 a
Arapaho	52.5 d	3.5 c	183.8 d	1,225.7 d
Guarani	76.6 c	5.3 a	412.4 b	2,750.2 c
Ébano	46.4 d	2.9 d	138.9 d	926.3 d
Choctaw	35.4 e	4.0 b	150.8 d	1,005.4 d
C.V. (%)	7.1	5.6	9.4	9.4
	Production cycle 2010/11 (1)			
Amora-vermelha	1,136.5 a	1.4 g	1,709.3 b	11,395.9 c
Xavante	76.6 e	3.5 d	222.7 e	1,274.7 f
Tupy	307.9 c	5.5 a	1,596.9 b	10,647.0 c
Caingangue	164.2 d	3.4 e	516.0 d	3,440.3 e
Comanche	386.2 c	3.9 c	1,411.2 b	9,412.5 c
Cherokee	159.0 d	3.1 e	451.5 d	3,012.3 e
Brazos	492.8 b	5.7 a	2,780.2 a	18,602.5 a
Arapaho	246.0 d	3.6 d	817.6 c	5,451.3 d
Guarani	475.8 b	5.4 a	2,269.3 a	15,129.8 b
Ébano	89.8 e	2.8 f	214.0 e	1,427.2 f
Choctaw	396.0 c	4.3 b	1,580.4 b	11,395.9 c
C.V. (%)	6.3	5.4	7.9	7.9

(1)Means followed by the same small letter in the column do not differ from one another by the Scott-Knott test ($p \leq 0.05$). (2)Calculation considering the spacing 3.0 x 0.5 m with the density of 6,667 plants ha^{-1}.

Table 3. Length, diameter, total titrable acidity, total soluble solids (STT, expressed in ºBrix) and ratio SST/acidity in fruits from the production cycle 2009/10 of plants of berries cultivars in Western Paraná, Brazil. Marechal Cândido Rondon, Paraná State, Unioeste, 2011.

Cultivars	Length (mm) [(1)]	Diameter (mm)	Total titrable acidity	Total soluble solids (SST, °Brix)	Ratio (SST/acidity)
Amora-vermelha	18.0 d	18.9 d	1.7 c	9.8 a	5.8 a
Xavante	16.6 e	17.3 e	2.3 a	8.6 b	3.7 c
Tupy	24.5 b	23.6 b	1.8 c	10.0 a	5.6 a
Caingangue	18.5 d	17.5 e	1.8 c	10.1 a	5.6 a
Comanche	21.5 c	20.9 c	2.4 a	8.6 b	3.6 c
Cherokee	17.5 d	18.5 d	2.2 a	9.2 a	4.2 b
Brazos	27.3 a	25.1 a	2.4 a	7.5 c	3.1 c
Arapaho	21.0 c	20.3 c	2.0 b	9.8 a	4.9 b
Guarani	25.2 b	24.2 b	2.3 a	10.4 a	4.5 b
Ébano	17.8 d	18.7 d	2.5 a	7.6 c	3.0 c
Choctaw	21.5 c	20.6 c	2.6 a	9.5 a	3.7 c
C.V. (%)	2.8	2.5	13.8	7.0	8.9

[(1)]Means followed by the same small letter in the column do not differ from one another by the Scott-Knott test ($p \leq 0.05$).

It should be emphasized that variations can occur in the chemical composition due to the differences in the intensity of the solar radiation rather than to differences in the site where the plants are grown and to temperature variation, which affect the organolepetic characteristics of blackberry fruits (ALI et al., 2011; SIRIWOHARN et al., 2004).

As temperatures during the crop cycle are very elevated in that region (Figure 1) and blackberry fruits are very delicate and perishable (ANTUNES et al., 2003), the ‘Brazos’ and ‘Guarani’ blackberry cultivars can be cultivated in the western region of the Paraná state due to the good yields obtained.

Another option aiming at the production of fruits in western Paraná, in addition to other regions, would be the cultivation of redberry fruits. That species (Rubus rosifolius), native to the Mantiqueira range (LORENZI et al., 2006), has not yet been studied in detail, but the results obtained in the present study are quite promising. The budbreak of the plants began in April during the first production cycle and during March in the second cycle, with a blooming duration of 173 days in the first production cycle and 248 days in the second cycle. In the second cycle, the recorded blooming period ranged between late March and late November; such that the fruit production ranged from May to January in the second cycle (a 245-day duration) (Table 1). The plants bore an average of 367 fruits in the first cycle and 1,136.5 fruits in the second cycle, but, due to the small size of the fruit (average mass of 1.5 g and sizes smaller than 18 mm), the yield per plant per cycle was 582.9 g and 1,709.3 g, respectively, presenting a yield of 11,395.9 kg ha^{-1} for the second production cycle (Table 2). Furthermore, the fruits possess low acidity and a high content of soluble solids (Table 3).

Conclusion

Most of the blackberry cultivars examined presented a production cycle longer than 90 days, with a harvest beginning in late October and extending through late January. The Brazos, Guarani and Tupy cultivars produced fruits of the greatest mass, but the greatest estimated yield was recorded for ‘Brazos’. Both ‘Tupy’ and ‘Cainguangue’ presented a good balance between the total soluble solids and acidity. The redberry tree presented a high fruit yield and was found to be an excellent option for processing.

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