ISSN 0100-2945 http://dx.doi.org/10.1590/0100-29452016141

PERFORMANCE OF BLACKBERRY CULTIVARS IN CERRO AZUL - PR[1]

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ABSTRACT -Blackberry has the potential to be grown in subtropical climates, requiring phenological studies for the indication of cultivars adapted to this type of climate. Thus, the aim of this work was to evaluate the phenological behavior of four blackberry cultivars, as well as to determine the physical and chemical characteristics of fruits produced in mesothermal subtropical climate (Cfa), with more focus on the recommendation of cultivars adapted to this region. The largest production cycle and the best productions and yields were obtained for Guarani cultivar and larger fruits were presented by Tupy cultivar. The best relationship between titratable acidity and soluble solids was presented by Cherokee cultivar.
Index terms: *Rubus*, phenology, postharvest, Tupy, Guarani, Xavante and Cherokee.

DESEMPENHO DE CULTIVARES DE AMOREIRA-PRETA EM CERRO AZUL-PR

RESUMO- A amoreira-preta tem potencial para ser cultivada em climas subtropicais, sendo necessários para isso estudos fenológicos para a indicação de cultivares adaptadas para estas regiões. Assim, objetivou-se com este trabalho avaliar o comportamento fenológico de quatro cultivares de amoreira-preta, bem como determinar a qualidade de seus frutos produzidos em Cerro Azul-PR, com foco na recomendação de cultivares mais adaptadas à região. O maior ciclo produtivo observado e as melhores produções e produtividades foram obtidos para a cultivar Guarani, e frutos maiores foram apresentados pela cultivar Tupy. Porém nenhuma cultivar atingiu a produtividade esperada nos primeiros dois ciclos produtivos. A melhor relação entre acidez titulável e sólidos solúveis foi apresentada pela cultivar Cherokee.
Termos para indexação: *Rubus*, fenologia, pós-colheita, Tupy, Guarani, Xavante e Cherokee.

INTRODUCTION

Among small fruits, blackberry is the second most cultivated species worldwide, mainly because fruits are rich in nutraceutical substances (FERREIRA et al., 2010;. CURI et al., 2015;. PEREIRA et al., 2015). In addition, fruits can be processed into a variety of products such as yogurts, jellies, jams and juices, and can also be consumed in the fresh form (ANTUNES et al., 2014; SOUZA et al., 2015). Regarding the production system, it is considered an easy management culture because plants are rustic and present high yields even without high use of agrochemicals (PEREIRA et al., 2015; ZIELINSKI et al., 2015).

This fruit tree has the potential to be grown in a wide range of climates, including subtropical climate due to the existence of cultivars with low chilling requirements such as Tupy (moderate cold need), the Xavante (low cold need) and Cherokee (intermediate to high cold need) (POLLING, 1996; GUEDES et al., 2013; PEREIRA et al., 2015). In addition to cold, heat is needed to stimulate growth and favor intense flowering, high production and also provide harvest anticipation (PIO; GONÇALVES, 2014; CURI et al., 2015).

The initiative of many farmers to revitalize and renew orchards and invest in increased planting area has been currently observed. However, the knowledge on the behavior of available blackberry cultivars is still scarce, and factors related to the characteristics of the species according to climatic conditions are decisive for the definition of productivity and quality of fruits in a certain place

[1](Trabalho 069-15). Recebido em: 09-03-2015. Aceito para publicação em: 02-12-2015.
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(STRIK et al., 2008; ANTUNES et al., 2014; CURI et al., 2015).

The concentration of information on blackberry cultivation is in temperate regions, and the potential for cultivation elsewhere remains little explored. Moreover, characteristics regarding climate adaptation of cultivars and the physical and chemical properties of fruits are different in relation to the cultivation sites (GUEDES et al., 2014; OSZMIAŃSKI et al., 2015).

Thus, the aim of this study was to evaluate the phenological behavior of blackberry cultivars and determine the quality of fruits under the conditions of Cerro Azul-PR, mesothermal subtropical climate.

MATERIAL AND METHODS

The cultivars studied were Tupy Guarani, Xavante and Cherokee. Seedlings were planted in 2011 with spacing of 1.0 x 4.0 m in the Municipality of Cerro Azul-PR, in an area whose coordinates are 24°53'S and 49°14'W and 659 m asl. The local climate, according to Köppen climate classification, is mesothermal subtropical (Cfa). Cultivation traits and fertilization followed the same pattern for all cultivars, which were performed according to soil analysis and technical recommendations for culture (ANTUNES; HOFFMANN, 2012).

The soil analysis performed before planting demonstrated the following nutrient content: P = 6.6 $mg.dm^{-3}$; C = 21.05 $mg.dm^{-3}$; Al = 0 $cmol.dm^{-3}$; H+Al = 4.96 $cmol.dm^{-3}$; Ca = 2.8 $cmol.dm^{-3}$; Mg = 2.1 $cmol.dm^{-3}$; K = 0.32 $cmol.dm^{-3}$; S = 5.22 $cmol.dm^{-3}$; CTC = 10.18 $cmol.dm^{-3}$; V = 51.27%; and pH = 5. The experimental design was a randomized block with four replications and six plants per plot and four taken as useful. The training system was vertical shoot position with three double rows of wires open in V shape.

In the 2012/2013 and 2013/2014 cycles, plants were evaluated weekly. Phenological evaluations were performed according to the description of the bud development stages (Antunes, 2000), on the dates of the beginning of flowering (more than 5% of open flowers), the end of flowering (90% of open flowers), early and final harvest. Fruits were harvested when they reached full maturity stage, that is, when the film reached a shiny black color (ANTUNES; HOFFMANN, 2012). The average production per plant (kg per plant) and production estimated per hectare (t ha^{-1}) were determined based on the plant density per hectare and dry weight of fruits.

For physical and chemical characterization of fruits, the following variables were analyzed: fresh weight (g); longitudinal and equatorial diameter (mm); skin color; pH; total soluble solids (TSS) and titratable acidity (TA). The experimental design was completely randomized, with four treatments, four replicates per treatment and 25 fruits per plot.

Fruit color evaluation was performed using a colorimeter, which evaluated the color difference among samples, as well as differences in hue and brightness among them. The parameters used were L *, a * and b *, and the hue of samples was determined from the b * and a * ratio. The total color difference was determined from the following equation:

Total color difference $(\Delta E) = (\Delta L^2+\Delta a^2+\Delta b^2)^{1/2}$

pH was evaluated with the aid of a pH meter with scale from 1 to 14, and the measuring electrode was directly inserted into the blackberry juice (INSTITUTO ADOLF LUTZ, 2005).

TSS content was measured in ° Brix using a refractometer, with direct reading by the addition of a fruit juice drop over the device prism (INSTITUTO ADOLF LUTZ, 2005).

TA was determined by neutralization titration according to methodology described by Reyes-Carmona (2005), in which a known volume of blackberry juice was titrated with 0.1 N NaOH until pH reached 8.2. The NaOH volume used was required to calculate TA, being expressed as citric acid percentage.

Results were submitted to analysis of variance (ANOVA), and when significant, means were compared by the Tukey test with $p \leq 0.05$.

RESULTS AND DISCUSSION

Accumulated rainfall data over the months in Cerro Azul-PR show that there was great variation among months and years on the site, with total rainfall ranging from 0 to 270.2 mm (Figure 1). For having a shallow root system, blackberry trees need regular water availability, which was not met in the region of Cerro Azul-PR. Moreover, in the 2012/2013 cycle, there was a rainfall concentration in the month of December, which may have contributed to the reduction in fruit quality, as plants were in the harvest phase. Too much rain concentrated at the end of the year can damage fruits and crops (CURI et al., 2015).

It was observed that in Cerro Azul-PR in both production cycles, there were low temperatures in the winter period, but high temperatures, above 20 ° C, were also observed (Figure 1). This thermal irregularity during the winter period is not suitable for cultivation because cold is crucial in this period to provide good budding rate and for blackberry plants to start a new growth cycle. Temperature fluctuations during this period can cause the plant to remain dormant for a longer period or the occurrence of uneven budding and flowering, directly interfering with plant productivity (SEGANTINI et al., 2014). In addition, average temperatures above 25 ° C encourage vegetative growth at the expense of reproduction growth in blackberry plants.

The flowering of Tupy Guarani and Xavante cultivars, which have lower chilling requirements compared with Cherokee cultivar, may be related to the onset of rains in September, as in August and in both production cycles, there was a period of water deficiency (Figure 2). This is because, in cultivars with moderate water needs at low temperatures, budbreak begins to occur when rains start and temperature rises (PIO; GONÇALVES, 2014).

Curi et al. (2015) observed anticipation in the sprouting period, in the production cycle, with higher average maximum temperatures, with consequent flowering anticipation in ten blackberry cultivars, including Tupy, Guarani, Xavante and Cherokee. Regarding the duration of the flowering period, these authors observed an increase in the number of days in the hottest cycle. This increase of higher temperatures was not observed in this work. However, the cultivar showing the shorter flowering period in both cycles was Cherokee. This fact is probably related to the higher chilling requirements of this cultivar. The longest flowering period was initially observed for Guarani cultivar, and then for Xavante cultivar (FIGURE 2). Curi et al. (2015) found no differences in the flowering period duration among Tupy Guarani, Xavante and Cherokee cultivars.

The prolongation of the blackberry tree flowering period is associated with insufficient low chilling and results in the occurrence of different phenological stages simultaneously on the same plant (SEGANTINI et al., 2014). The end of flowering and beginning of harvest were very close for some cultivars, and lack of definition regarding the developmental stage has been observed in many plants, with the occurrence in the same branch of buds, flowers and fruits. Curi et al. (2015) also observed simultaneous flowering and harvesting phases of these cultivars when planted in tropical climate at elevation.

The harvest period in the 2012/2013 cycle was higher for Tupy Guarani and Xavante cultivars, and the peak of this phase coincided for these three cultivars, with no production staggering. In addition, the harvest of all cultivars under study in temperate climate conditions also started from November (ANTUNES et al., 2010). Thus, the expectation that the warmer climate would provide anticipation of the harvest period has not been verified.

According to Antunes et al. (2014), blackberry productivity can reach up to 25 t ha^{-1} yr^{-1} under suitable conditions and management, and productions of 10-16 t ha^{-1} yr^{-1}, on average, are observed. The best production and productivity in Cerro Azul-PR were observed for Tupy and Guarani cultivars in the 2012/2013 cycle, and Guarani in the 2013/2014 cycle, but the values found were below expectations (Table 1). One of the factors that certainly contributed to this result was the low soil fertility level and the impossibility of using organic fertilizers due to the low availability of this product in the region.

Although the damage in the field has not been quantified, the presence of pests such as leaf beetles, ants and blackberry borer was observed, and the attack intensity was higher in the 2013/2014 cycle. This certainly contributed to the low productivity observed, especially in respect to Tupy cultivar, which seemed to be the most susceptible to the attack of pests. However, further studies should be performed to identify the main pests of this culture in these conditions and point the integrated management.

Among the four studied cultivars, Cherokee has the highest chilling requirement (POLING, 1996). As its demand was not met in this climate, low yields were obtained in both cycles. Curi et al. (2015) found productivities of 2,241 and 4,475 kg / ha for this cultivar in tropical climate at elevation for the first and second cycles, respectively. These values were higher than those obtained in this study. However, the same authors also observed higher productivities for Tupy and Guarani cultivars.

Regarding weight, Tupy cultivar fruits weighted on average 8.1 g in 2012/2013 (Table 1). Pereira et al. (2015) found for this cultivar in temperate region, weights ranging from 8 to 10 g for increasing doses of potassium fertilization in the first production cycle. In the second cycle, weights ranged from 6 to 7 g. These data demonstrate that this cultivar may have good adaptability to the region. Antunes et al. (2010) evaluated five cultivars and two blackberry selections also in temperate climate and found significant differences in the weights of fruits that, in general, were lower than values obtained in this work. Greater weights are directly related to greater fruit diameter (Table 2).

Physiologically, plants show an inverse relationship between number of fruits and fruit size (PAVANELO; AYUB, 2012). Larger sizes are obtained when the plant produces fewer fruits, and as production was low, fruits produced were larger. Fruits with larger longitudinal and equatorial diameters were presented by Tupy cultivar in both cycles and by Xavante cultivar in 2013/2014. Curi et al. (2015) found higher diameters for Tupy Guarani and cultivars in relation to Xavante and Cherokee. Zielinski et al. (2015) found diameters ranging from 23.10 to 28.03 mm for Tupy cultivar, results similar to those obtained in this work.

Color is an important parameter for farmers and consumers as it indicates whether the fruit presents or not optimal conditions for marketing and consumption. In general, consumers have a preference for fruits with strong and bright color (CECCHI, 2003). In this way, variations were observed among fruits for ΔE parameter, which indicates the total difference in the color of samples (TABLE 2). Less dark colorations were observed for blackberries Tupy cultivar in 2012/2013 and Xavante cultivar in 2013/2014.

The perception of color by our visual system is three-dimensional, and the ΔE value alone is not sufficient to predict the color of a sample (NINDO et al., 2003). Thus, for best resolution, the L * values (brightness) were plotted against the b * / a * ratio, which indicates the fruit hue value (FIGURE 3).

It is evident that cultivars are different in terms of color, and Xavante cultivar showed fruits with more brightness and greater amount of red color compared to blue, and Tupy cultivar showed fruits with lower brightness and higher amount of blue color compared to red. Moreover, Cherokee cultivar showed fruits with the greatest amount of blue color among all cultivars, which interferes with color perceived by our vision and can influence the consumer's purchase decision.

The pH value of fruits ranged from 3.0 to 3.3 without significance in the analysis of variance among the different cultivars (TABLE 3). The pH values are low due to the natural characteristics of acid taste and sweet acid taste of fruits (ANTUNES et al., 2014). This is a desirable feature for industrialization. The system pH, for example, directly affects the formation of gels to produce jellies, and the optimum conditions for this formation occur for pH near 3.2. Furthermore, maintaining a low pH in the fruit is important to assure retention of taste and odor to the product (CECCHI, 2003). Souza et al. (2014) found average pH of 3.0 in blackberries grown in southern state of Minas Gerais (tropical climate at elevation), which confirms the values found here.

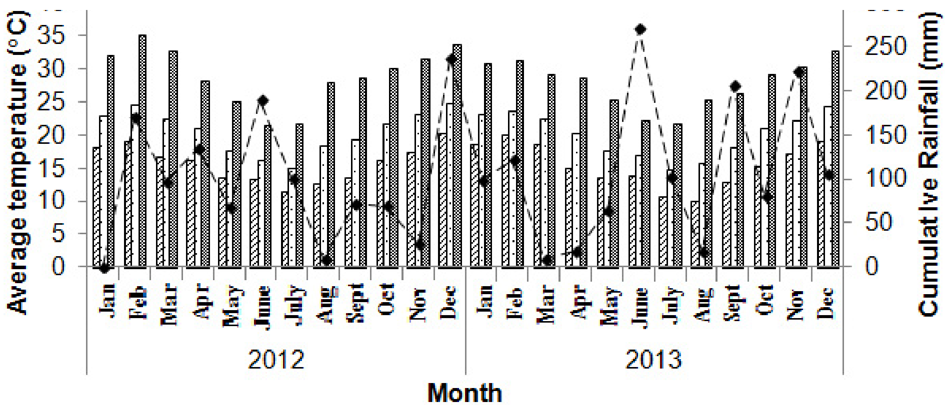
Titratable acidity is an important parameter related to the presence of organic acids that also influence taste, odor, color, stability and food quality maintenance (CECHI, 2003). Blackberries evaluated in this study showed titratable acidity values between 0.9% and 2.7% citric acid, but there was significance in the analysis of variance of samples only in 2013/2014, and Cherokee cultivar was the most acidic in this period (TABLE 3). Hassimotto et al. (2008) found differences in the citric acid content of Tupy and Guarani blackberries, with Tupy fruits presenting lower acidity. Hirsch et al. (2012) found no significant differences for this property in Tupy, Guarani and Cherokee blackberries. Zielinski et al. (2015) found decreasing titratable acidity values for Tupy cultivar (1.37% to 0.92% citric acid) according to the harvest time, indicating that the acid content of blackberries decrease with maturation.

The TSS content of samples, which is indicative of sugar content ranged from 7.6 to 9.3 °Brix, with differences among cultivars (TABLE 3). In 2012/2013, Xavante cultivar showed lower TSS values, which was expected because it is a characteristic of this cultivar producing slightly bitter fruits. By contrast, in 2013/2014, Tupy cultivar showed fruits with the lowest TSS levels. This result is surprising, because Tupy cultivar is reported in literature to have sweeter fruits, with TSS content between 8 and 9 °Brix (ANTUNES et al., 2014). However, Hassimoto et al. (2008) found total soluble solids content of 6.9 °Brix for Tupy cultivar in tropical climate. This may indicate that, in warmer climates, blackberries do not reach adequate TSS content.

The sourer taste observed for Tupy cultivar can also be a consequence of the attack of pests that primarily occurred in this cultivar. This is because the incidence of pests caused severe defoliation in Tupy plants, decreasing the photosynthetically active area and thus reducing the production of assimilates transported into the fruit. Dixon et al. (2015) found significant interactions between TSS content and cultivar, the irrigation season and the occurrence of weeds, which indicates that this content can be changed according to the management adopted and the environmental conditions.

The best relationship between TSS and TA was presented by Cherokee cultivar in 2013/2014, indicating that its fruits have better taste among cultivars, when produced in the region of Cerro Azul-PR. Pio and Gonçalves (2014) reported that the balance between acidity and sugar for blackberries occurs with relationship between TSS and TA next to 9.0. However, Souza et al. (2014) found average ratio of 6.7 for blackberries harvested in tropical climate. In turn, Hassimoto et al. (2008) found values ranging from 4.0 to 7.4 in different cultivars also implemented in tropical climate. These values suggest that higher temperatures can disrupt the balance between acidity and sugars in fruits.

The development of blackberry cultivars with low chilling requirements has allowed the planting of this species in subtropical and tropical regions, such as São Paulo and Minas Gerais (ANTUNES et al., 2014). However, with the results presented in this study, it was observed that the orchard management in this region requires further studies adapted to local conditions.



MINIMUM TEMPERATURE ; AVERAGE TEMPERATURE ; MAXIMUM TEMPERATURE ; CUMULATIVE RAINFALL).

FIGURE 1 - Monthly minimum, average and maximum temperatures (° C) and cumulative rainfall (mm) in years 2012 and 2013. Cerro Azul-PR (Simepar).

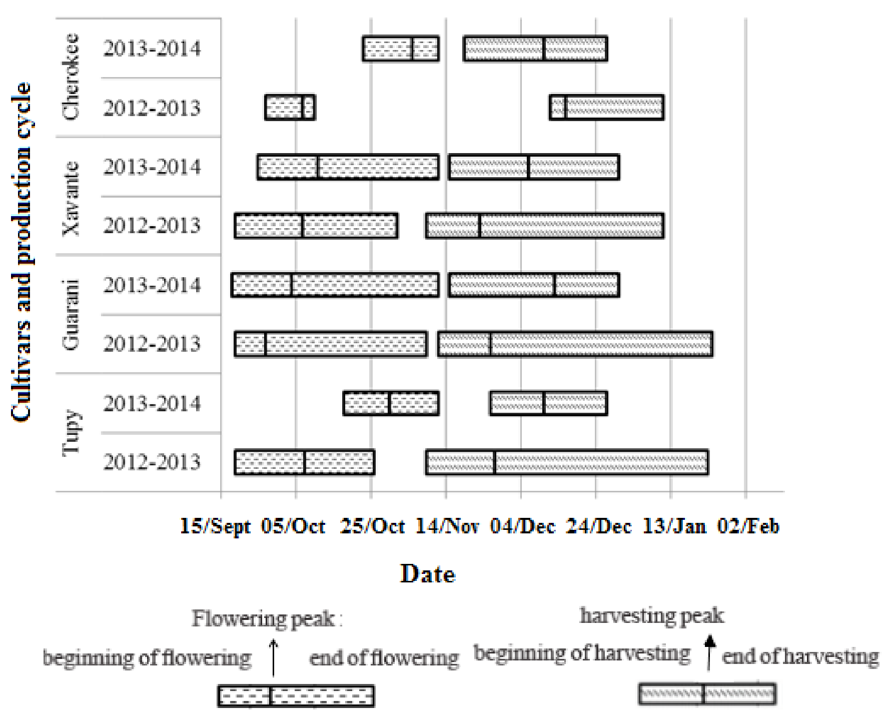


FIGURE 2 - Flowering and harvesting period of blackberries in production cycles of 2012/2013 and 2013/2014. Cerro Azul - PR.

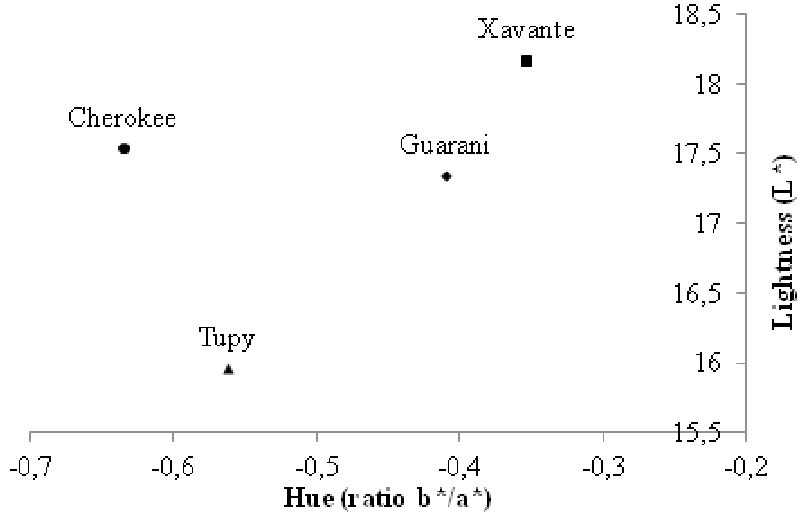


FIGURE 3 - Hue and brightness values of blackberry fruits in 2013/2014. Cerro Azul-PR.

TABLE 1 - Production performance of blackberry cultivars in 2012/2013 and 2013/2014 cycles. Cerro Azul-PR.

	Production ($g\ plant^{-1}$)		Productivity ($kg\ ha^{-1}$)		Weight ($g\ fruit^{-1}$)	
	2012/2013	2013/2014	2012/2013	2013/2014	2012/2013	2013/2014
Tupy	1.291.2a	260.8c	3.228.1a	651.9c	8.1a	7.8a
Guarani	1.099.5a	2.028.9a	2.748.7a	5.072.3a	4.8b	3.5c
Xavante	205.9b	1.576.8b	514.8b	3.942.1b	4.7b	4.7b
Cherokee	171.8b	295.8c	429.5b	739.5c	3.3c	4.7b
VC (%)	16.02	12.09	16.02	12.09	7.72	5.44

Averages followed the same letter in column do not differ. tukey test $p \leq 0.05$.

TABLE 2 - Average longitudinal and equatorial diameter and total color difference (δe) of blackberries in 2012/2013 and 2013/2014 cycles. Cerro Azul-PR.

	Longitudinal diameter (mm)		Equatorial diameter (mm)		Color difference (ΔE)	
	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14
Tupy	28.3a	22.9a	23.6a	18.7a	9.0b	9.6a
Guarani	22.6b	18.5b	20.3ab	16.7ab	13.2a	8.7a
Xavante	21.9b	21.1a	19. 7b	18.1a	11.2ab	7.8b
Cherokee	16.9c	14.2c	17.3b	13.7b	11.9a	8.0ab
VC (%)	4.12	3.89	4.08	3.21	9.82	9.81

Averages followed the same letter in column do not differ between. Tukey Test $P \leq 0.05$.

TABLE 3 - Chemical properties of blackberry fruits in 2012/2013 and 2013/2014 cycles. Cerro Azul-PR.

	pH		Titratable acidity (% citric acid)		Soluble Solids (ºBrix)		(SS/AT) Ratio	
	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14	2012/13	2013/14
Tupy	3.0^{ns}	3.0^{ns}	2.4^{ns}	1.1b	8.4ab	7.6b	3.4b	6.5b
Guarani	3.1	3.1	2.7	1.3a	9.0a	8.7a	3.3b	6.5b
Xavante	2.9	3.1	2.5	1.5a	8.0b	8.8a	3.2b	5.9b
Cherokee	2.9	3.3	2.0	0.9c	9.2a	8.8a	4.6a	10.1a
CV (%)	3.16	4.15	13.80	8.64	5.36	5.76	7.23	7.12

Averages followed the same letter in column do not differ. tukey test $p \leq 0.05$. ns: not significant.

CONCLUSION

In Cerro Azul-PR, the best results were observed for Guarani cultivar. However, productivity was below the average of this cultivar in other regions. The largest fruits were produced by Tupy cultivar.

ACKNOWLEDGMENTS

To IAPAR for providing the Experimental Station facilities of Cerro Azul and for the support of its technical staff and CNPq for financial support.

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