

Performance of ‘Tupy’ and ‘Xavante’ blackberries under subtropical conditions

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Summary

Introduction – An increasing interest in blackberry consumption worldwide demands higher production, both for fresh and processed industries. Blackberry cultivation in subtropical conditions may be used to extended areas of worldwide production by using high yielding cultivars. The objective of this study was to evaluate the performances of ‘Tupy’ and ‘Xavante’ blackberries under subtropical conditions, with the aim of increasing the availability of cultivars with high yields and adaptation to low input conditions.

Materials and methods – Evaluations were conducted at the Experimental Station at Londrina State University, PR, Brazil, during two consecutive seasons, 2013 and 2014. The variables evaluated were length, diameter, weight, total soluble solids (TSS), titratable acidity (TA), TSS/TA ratio, pH, color, total berry anthocyanin and polyphenol concentrations, yield and the percentage distribution of the cumulative yield.

Results and discussion – Considering all the evaluated variables, ‘Xavante’ presented berries with poorer physical characteristics and had lower yields than ‘Tupy’. However, ‘Xavante’ had good chemical characteristics and a higher percentage of early cumulative yield compared to ‘Tupy’ blackberry. ‘Tupy’ produced large fruits with optimum TSS and pH values, presented an attractive color, and obtained high yields and a higher percentage distribution of the cumulative yield towards the end of the harvest season. The production of these cultivars under subtropical conditions could be a good choice for growers to commercially produce fruit for fresh consumption and the processing industry due to their good yield and optimum quality attributes.

Conclusion – The good adaptation of ‘Tupy’ and ‘Xavante’ blackberries to subtropical areas allows growers to produce fresh fruit using agroecological management. This management allows for an early harvest within approximately two months and an expanded harvest season to fulfill the market demand for fresh consumption.

Keywords

Brazil, small fruits, *Rubus* spp., growing conditions, agronomic characteristics, crop yield

Significance of this study

What is already known on this subject?

- Blackberry is a temperate species that is a good cultivation option for small-scale growers due the low cost of development and maintenance of orchards with a quick and high economic return due to an expanded market and an increased consumption worldwide.

What are the new findings?

- Although the cv. Xavante presented lower yields than ‘Tupy’, its good chemical properties and earliness make it appropriate for large-scale growth with early production and extended harvest period in a short and mild winter climate. The cv. Tupy had an overall good adaptation to subtropical conditions, relatively large size fruits with optimum TSS, and high fruit yield throughout the harvest season.

What is the expected impact on horticulture?

- The production of low-chilling blackberry cultivars in subtropical conditions, with mild and short winter using agroecological management without synthetic inputs, is a good choice for commercial growers to combine fruit production for fresh consumption and processed industry. This allows for early harvesting and expanded harvest season to fulfill the market demand during periods of low supply.

Résumé

Performance des mûres ‘Tupy’ et ‘Xavante’ dans des conditions subtropicales.

Introduction – L’intérêt croissant de la consommation des mûres dans le monde entier exige une production plus élevée, pour les industries à la fois des produits frais et des produits transformés. La culture des mûres en conditions subtropicales pourrait permettre d’étendre la zone de production dans le monde entier. L’objectif de ce travail était d’évaluer la performance des mûres ‘Tupy’ et ‘Xavante’ dans des conditions subtropicales, en visant la disponibilité de cultivars à fort potentiel de rendement et adaptés à un faible niveau d’intrants. **Matériel et méthodes** – Les tests ont été menés sur la station expérimentale de l’Université d’Etat de Londrina, PR, Brésil, sur deux

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saisons consécutives (2013 et 2014). Les variables évaluées sont: la longueur, le diamètre, le poids, les solides solubles totaux (SST), l'acidité titrable (AT), la relation SST/AT, le pH, la couleur, les anthocyanes totales et la concentration des fruits en polyphénols, le rendement et la répartition en pourcentage du rendement cumulatif. Résultats et discussion – En tenant compte des variables évaluées, ‘Xavante’ a présenté des caractéristiques physiques du fruit et un rendement inférieurs à celles de ‘Tupy’, mais de bonnes caractéristiques chimiques et une distribution précoce du rendement cumulatif. Les fruits produits par ‘Tupy’ présentaient une grande taille avec un SST et un pH optimaux, avaient aussi une couleur attrayante, et ont obtenu un rendement élevé et une distribution de pourcentage de rendement cumulatif plus élevée vers la fin de la saison de la récolte. La production de ces cultivars dans des conditions subtropicales peut être un bon choix pour les cultivateurs, permettant la production commerciale de fruits pour la consommation en frais et pour l'industrie de transformation grâce à un bon rendement et à des attributs de qualité optimaux. Conclusion – La bonne adaptation des mûres ‘Tupy’ et ‘Xavante’ aux conditions subtropicales doivent permettre aux cultivateurs de produire aisément des mûres fraîches sur un modèle de gestion agroécologique. Cela permet en particulier une récolte précoce permettant de satisfaire la demande du marché en frais pendant environ deux mois, avec une période de récolte élargie.

Mots-clés

Brésil, petits fruits, *Rubus* spp., conditions de culture, caractéristiques agronomiques, rendement de culture

Introduction

Changes in the eating habits and the increase of the purchasing power of the population in some countries have increased the demands for fresh fruit production. Sales of fresh small fruit, such as blackberry (Fachinello *et al.*, 2011), offer good growing and marketing prospects.

Blackberry, known as *Rubus* subgenus *Rubus* Watson, belongs to the Rosaceae family and has become an important cultivated species in American countries, such as Mexico, the United States, and more recently, Brazil (Clark and Finn, 2014). Native to Asia, Europe and America and well-suited to regions with a well-defined winter (Moore, 1984), blackberry is a temperate species that is a good cultivation option for small-scale growers due the low cost of development and maintenance of orchards with a quick and high economic return (Antunes *et al.*, 2000; Antunes, 2002).

Blackberries have high levels of phenolic compounds, vitamin C (which can help prevent degenerative diseases) and natural pigments (mainly anthocyanins, which are attractive colorants used in the food industry) (Tiwari *et al.*, 2009; Acosta-Montoya *et al.*, 2010; Ali *et al.*, 2011). These attributes have led to the increased use of blackberries production of products, such as yogurts, jellies, sweets and juices, high in nutraceutical properties, as well as being sold as fresh fruit, and as frozen pulp (Hussain *et al.*, 2014; Antunes *et al.*, 2014; Souza *et al.*, 2014).

Traditional production regions in temperate zones do

not sufficiently meet the demands of the expanded market and overall increase in consumption worldwide. Newer cultivars from breeding programs in North and South America have expanded the range of adaptation into regions with low chill conditions. Thus, there is an opportunity to expand the blackberry growing area into subtropical zones which offer favorable climatic conditions to meet the increased demand (Antunes, 2002; Strik *et al.*, 2008; Tadeu *et al.*, 2015).

‘Tupy’ and ‘Xavante’ are the most important blackberry cultivars grown in warm temperate areas due to their high yields and fruit quality (Clark and Finn, 2014; Antunes *et al.*, 2000; Volk *et al.*, 2013), but there is little information available on the behavior of these cultivars in subtropical conditions. The number of blackberry growers and production in subtropical areas is limited due to the lack of knowledge, insufficient research, inappropriate use of cultivars for a specific market, the use of cultivars not adapted to climatic conditions, and poor management of the harvest (Antunes *et al.*, 2014).

Considering the aspects above, the present study was conducted to investigate the performances of ‘Tupy’ and ‘Xavante’ blackberry cultivars under subtropical conditions, aiming to increase the availability of cultivars with improved yield and adaptation to low input conditions.

Materials and methods

Experimental site and blackberry cultivars

Evaluations were conducted at the Experimental Station at Londrina State University, PR, Brazil (latitude 23°23'S, longitude 51°11'W and elevation of 566 m a.s.l.), during two consecutive growing seasons, 2013 and 2014. According to the Köppen classification system, the climate of the region is Cfa (subtropical climate), with an average temperature of less than 18 °C during the coldest month (mesothermal), an average temperature more than 22 °C during the hottest month, and an average annual rainfall of 1,507 mm (Koyama *et al.*, 2014). The texture of the soil is 81% clay, 8% silt and 11% sand.

‘Tupy’ and ‘Xavante’ blackberries (*Rubus* sp.) were chosen due to their high yields and adaptation worldwide. Moreover, these cultivars are easy to propagate by cuttings and are temperature resistant. ‘Tupy’ is a hybrid between ‘Comanche’ blackberry and ‘Boysenberry’, and it is considered an important global cultivar due to its high yield and excellent fruit quality. ‘Tupy’ produces black fruit and has vigorous, spiny stems with a prostrate growth habit that requires support and training. ‘Xavante’ is derived from open pollinated seeds collected in Clarksville, Arkansas, USA, from plants from a cross between ‘A1620’ and ‘A1507’ blackberries and is, therefore, the second generation of this cross. ‘Xavante’ is an early and vigorous cultivar with upright spineless stems, a low-chilling requirement and good production (Clark and Finn, 2014; Antunes *et al.*, 2000; Hussain *et al.*, 2014).

Nursery stock of both blackberry cultivars was produced according the Villa *et al.* (2003) methodology and resource plants from Embrapa Temperate Agriculture facility at Pelotas, Brazil. The nursery plants were spaced at 3 m between rows and 1 m between plants in November 2012. The plants were trained on a double cordon trellis of two wires (parallel twin wires) on eucalyptus “T” poles that were spaced 60 cm apart at a height of 90 cm above the ground level.

The experimental design was a completely randomized block with two treatments (‘Tupy’ and ‘Xavante’ blackber-

ries) and ten replicates. Each plot was composed of five bushes of each blackberry cultivar.

Agronomical practices

During the experiment, identical cultivation practices were employed for both cultivars. Irrigation of the experimental plants was performed with a drip system, using an agroecological management system without the use of synthetic inputs and with regular manual weed control. Farmyard manure was applied one week after pruning.

In the 2013 and 2014 seasons, pruning was completed in late winter on August 9th and August 6th, respectively, leaving an average of five stems per plant up to the second wire of the cordon. In this step, branches were trimmed to a height of 10 cm above the second support wire and the side branches were eliminated.

Physicochemical characteristics of the fruit

As blackberry flowering and harvest occur continuously over several weeks, the physicochemical characteristics of fruit from each cultivar, from the beginning of harvest, were evaluated weekly using berries hand harvest early in the morning and placed in plastic boxes. For each cultivar, a sample of 50 berries was collected from each plot every week in 10 replicates, *i.e.*, 10 berries per plant in each plot. Then, the following variables were evaluated: length, diameter, fresh weight, total soluble solids (TSS), titratable acidity (TA), maturation index (TSS/TA), pH, color, total anthocyanins, polyphenols, berry production per bush and yield. The number of weekly samples collected were 9 and 7 for the 2013 and 2014 growing seasons, respectively.

The physical characteristics of the fruit, such as diameter (cm), length (cm), fresh weight (g) and color, were evaluated using a sub-sample of 20 berries per plot. The external color of the berries from each cultivar was analyzed using a colorimeter Minolta CR-10®, and the following variables were obtained from the berry equatorial portion ($n = 2$): L^* (lightness), C^* (saturation) and h° (hue) (Tullio and Ayub, 2013). Lightness values range from 0 (black) to 100 (white). Chroma indicates the purity or intensity of the color or the distance from gray (achromatic) towards a pure chromatic color and is calculated from the a^* and b^* values on the CIELab scale system, which starts at zero for a completely neutral color, does not have an arbitrary end, and increases with magnitude. Hue refers to the color wheel and is measured in angles, with green, yellow and red corresponding to 180°, 90° and 0°, respectively (Lancaster *et al.*, 1997; Macguire, 1992; Peppi *et al.*, 2006).

For the chemical characteristics of fruits, such as TSS and TA contents, a sub-sample of 30 berries per plot was macerated, and the obtained juice was analyzed using a digital refractometer with automatic temperature compensation (Model DR301-95, Kruss Optronic, Germany). The results for TSS were expressed in °Brix. Measurements of TA content were obtained by titrating the juice with a standardized solution of 0.1 N NaOH, using pH = 8.2 as the end point. The result was expressed as the percentage of citric acid (AOAC, 1990). Before TA evaluation, the pH of the juice was also determined.

The total anthocyanin and polyphenol concentrations in the berries of each cultivar were measured according to the methodology described by Clemente and Galli (2013), and Borges *et al.* (2013). For these analyses, the same sub-sample of 30 berries per plot that was employed for TSS and TA analysis was used. For the total anthocyanin concentration, 50 g

of macerated berries from each plot were homogenized with 200 mL of extracting solution (70 mL of 70% ethanol and 30 mL of 0.1% HCl at pH 2.0) for 2 min in a blender and then placed in a beaker covered with Parafilm® and aluminum foil for 12 h at 4 °C. Next, the mixture was filtered and the filtrate was transferred to a 250-mL volumetric flask before adding an extracting solution. An aliquot of 2.0 mL was taken from the stock solution at 4.0 ± 0.5 °C and transferred to a 25-mL volumetric flask. The remaining volume was filled with extracting solution, and the flask was stored at room temperature in the darkness for 2 h. The extracting solution was used as the blank. The absorbance was determined at 535 nm using a spectrophotometer (Thermo Scientific, Genesys™, 10S UV-Vis), and readings were expressed as mg 100 g⁻¹ berries. For the total polyphenol concentration, 5 g of macerated berries from each plot was mixed with 50 mL of 50% ethanol for 2 min and then centrifuged at 3,500 rpm for 5 min. A 0.2-mL aliquot of the extract was mixed with 1.8 mL of distilled water and 10 mL of a 10-fold dilution of the Folin-Ciocalteu reagent. After 30 s to 8 min, 8 mL of a 7.5% of Na₂CO₃ solution was added. All test tubes containing the mixture were shaken for 10 s on the vortex and stored in darkness for 2 h. The absorbance of each sample at 765 nm was measured after 15 min using a spectrophotometer (Thermo Scientific, Genesys™, 10S UV-Vis) and compared with the absorbance of the blank sample. The blank sample was prepared with water instead of the extract. The total polyphenol concentration of each sample was calculated from the calibration curve obtained with gallic acid, and readings were expressed as mg 100 g⁻¹ of berries (gallic acid equivalent).

Yield parameters

The production per bush of each cultivar (kg bush⁻¹) was obtained by summing each weekly harvest, and the yield (kg ha⁻¹) was estimated according to the orchard density. The percentage distribution of the cumulative yield over the trial weeks was also obtained for each cultivar during both seasons.

Statistical analyses

The data were analyzed using Student's test for independent samples with homogeneity of variances verification; means and standard deviation were assessed with a significance level of 5%. The means represented the average of 9 and 7 weekly samplings of the 2013 and 2014 seasons, respectively.

Results and discussion

Physical characteristics of the fruit

Significant differences were observed between the mean lengths, diameters and weights of the berries, with the 'Tupy' resulting in higher values than the 'Xavante' blackberries during both seasons (Table 1). These traits are considered genetic characteristics of cultivars. In addition, the subtropical climate appears suitable and favors good size and weight for berry development, similar to fruit development in temperate zones (Eyduvan *et al.*, 2008).

Among the blackberry characteristics, one of the most appreciated by consumers is the fruit size. Berry size and weight also have a direct effect on the marketability and acceptance of blackberries for both fresh and processed markets and have a strong influence on yield. Traditionally, large fruits are preferred by consumers and the processing industry (Clark and Finn, 2011). The optimum fruit quality under

TABLE 1. Means of fruit length, diameter and weight of ‘Tupy’ and ‘Xavante’ blackberries, seasons 2013 and 2014.

Cultivars	Fruit length (cm)		Fruit diameter (cm)		Fruit weight (g)	
	2013	2014	2013	2014	2013	2014
‘Tupy’	2.80 ± 0.04*	2.80 ± 0.06*	2.10 ± 0.06*	2.30 ± 0.03*	6.00 ± 0.20*	6.20 ± 0.11*
‘Xavante’	2.30 ± 0.06	2.40 ± 0.06	1.90 ± 0.03	1.90 ± 0.03	4.40 ± 0.51	5.10 ± 0.10

Student’s test for independent samples with homogeneity of variances verification with means ± standard deviations.

*: significant at $P < 0.05$.

subtropical conditions observed for both cultivars indicates that ‘Tupy’ and ‘Xavante’ fruits are suitable for fresh marketing (Fernandez and Ballington, 2010).

Chemical characteristics of the fruit

One of the most important chemical characteristics of berries is the total soluble solids (TSS) content, which is used as an indirect measure of the sugar content (Hirsch *et al.*, 2012). However, no significant difference was observed regarding this variable when the berries from cultivars were compared in both seasons (Table 2). The TSS content observed for the ‘Tupy’ and ‘Xavante’ in this study favored the use of both cultivars for numerous purposes, such as fresh fruits and processed products, as 10 °Brix is an optimum value for good flavor (Clark and Finn, 2011). On the other hand, lower TSS contents were observed in ‘Tupy’ and ‘Xavante’ cultivated in a temperate region, with 9 and 8 °Brix, respectively (Antunes and Raseira, 2004). These findings clearly indicate that when both cultivars are grown in a subtropical climate, a positive difference may be achieved regarding quality attributes, such as TSS, according to Prange and DeEll (1997).

Significant differences were observed for titratable acidity (TA) and TSS/TA during seasons 2013 and 2014, with lower TA values observed for ‘Tupy’ berries than ‘Xavante’ (Table 2). Regarding the TSS/TA ratio, ‘Tupy’ berries had a higher ratio than ‘Xavante’. The pH values measured in fully ripe blackberries were low due to their natural acidic taste and sweet/acidic taste, which are desirable attributes for the processing industry and for fresh consumption. TA and TSS/TA ratio are important berry quality characteristics related to flavor and indicate the proper harvest time (Shaw, 1988; Cordenunsi *et al.*, 2002; Vrhovsek *et al.*, 2008). pH is also an

important characteristic for use in the industrial production of jams and jellies, with a preferred pH of 3.0–3.2 (Hirsch *et al.*, 2012). Thus, the lower TA observed for ‘Tupy’ and the optimum TSS/TA ratio makes it a good option for fresh consumption as reported by Lewers *et al.* (2010), who observed that the optimal flavor of blackberries was obtained in berries with a TSS/TA ratio of approximately 10, which is achieved with high levels of each component or with moderate TSS and low TA.

In the 2013 season, no differences between cultivars were observed for lightness (L^*), indicating dark black surface color (Table 3). For saturation (C^*), it was observed that ‘Tupy’ presented higher saturation levels than ‘Xavante’ berries in both seasons, indicating purer color. For hue angle (h°), a significant difference between ‘Tupy’ and ‘Xavante’ was observed; the ‘Tupy’ berries had higher hue angles than the ‘Xavante’. Both cultivars presented similar color attributes, with full shiny black color and no red or reddish drupelets at the time of harvest, in accordance with consumer preferences (Hirsch *et al.*, 2012). Berry color is an important variable for producers and consumers, which indicates whether the present berry condition is ideal for marketing and consumption. In other words, berry color is an indirect indicator of berry ripening. Additionally, as blackberries are non-climacteric fruit, they were harvested at full ripeness with maximum quality and color attributes in this trial and were ready for consumption (Cordenunsi *et al.*, 2002).

Another way to evaluate the adaptation of blackberries to a new area is through variations in pigment concentrations due to accumulated content of anthocyanins, a natural group of pigments composed of organic compounds (Hari *et al.*, 1994; Delgado-Vargas *et al.*, 2000). However, no significant difference was observed for the concentration of total

TABLE 2. Means of total soluble solids (TSS), titratable acidity (TA), TSS/TA and pH of ‘Tupy’ and ‘Xavante’ blackberries, seasons 2013 and 2014.

Cultivars	TSS (°Brix)		TA (% citric acid)		TSS/TA		pH	
	2013	2014	2013	2014	2013	2014	2013	2014
‘Tupy’	10.9 ± 0.3 ^{ns}	1.20 ± 0.07*	9.1 ± 0.3*	3.20 ± 0.03 ^{ns}	1.20 ± 0.05*	11.3 ± 0.2 ^{ns}	9.1 ± 0.3*	3.20 ± 0.03 ^{ns}
‘Xavante’	10.8 ± 0.2	1.40 ± 0.04	7.9 ± 0.5	3.20 ± 0.04	1.30 ± 0.05	11.1 ± 0.3	7.9 ± 0.5	3.20 ± 0.04

Student’s test for independent samples with homogeneity of variances verification with means ± standard deviations.

*: significant at $P < 0.05$, ^{ns}: not significant.

TABLE 3. Means of lightness (L^*), saturation (C^*) and hue angle (h°) of ‘Tupy’ and ‘Xavante’ blackberries, seasons 2013 and 2014.

Cultivars	L^*		C^*		h°	
	2013	2014	2013	2014	2013	2014
‘Tupy’	18.1 ± 0.4 ^{ns}	18.2 ± 0.4*	2.7 ± 0.2*	2.5 ± 0.2*	13.1 ± 0.4*	13.3 ± 0.1*
‘Xavante’	18.3 ± 0.3	19.2 ± 0.5	2.3 ± 0.2	2.2 ± 0.2	12.6 ± 0.6	12.7 ± 1.3

Student’s test for independent samples with homogeneity of variances verification with means ± standard deviations.

*: significant at $P < 0.05$, ^{ns}: not significant.

TABLE 4. Means of total anthocyanins and polyphenols of 'Tupy' and 'Xavante', seasons 2013 and 2014.

Cultivars	Total anthocyanins (mg 100 g ⁻¹)		Total polyphenols (mg 100 g ⁻¹)	
	2013	2014	2013	2014
'Tupy'	36.2 ± 3.1 ^{ns}	35.5 ± 2.7 ^{ns}	65.9 ± 6.1*	62.9 ± 6.2*
'Xavante'	34.4 ± 2.8	34.4 ± 1.6	84.3 ± 7.8	86.3 ± 9.1

Student's test for independent samples with homogeneity of variances verification with means ± standard deviations.

*: significant at $P < 0.05$. ^{ns}: not significant.

anthocyanin in the fresh fruits of both blackberry cultivars (Table 4).

The determination of phenolic compounds in blackberry cultivars grown in subtropical areas is very important because consumers look for foods that are able to improve quality of life. When total polyphenols were analyzed, a significant difference was observed, in which 'Xavante' berries had higher phenolic compound concentrations than 'Tupy' in both seasons (Table 4), which could be attributed to the genetic variability among cultivars and not the subtropical conditions, as observed by Sellappan *et al.* (2002) and Jacques *et al.* (2009). Further, Pantelidis *et al.* (2007) observed that the anthocyanin and polyphenol concentrations were lower in blackberry cultivars with spines than in spineless cultivars, which was also observed in this study since 'Tupy' presents spiny stems. However, the differences are rather due to plants of different genetic background. If spiny seedlings are grown from crosses between the spineless seedlings and spiny types, then they too have higher anthocyanin and polyphenol concentrations.

Yield

Regarding yield, significant differences were observed between the cultivars during both the 2013 and 2014 seasons. 'Tupy' showed higher production per bush than 'Xavante' during the two crop seasons (Table 5). 'Tupy' produced in 2014 double the production of 2013, and 'Xavante' maintained the same mean yield in 2013 and 2014.

Yield-genotypic response under given environmental conditions is considered a basic variable for any crop in a different growing climate (Lewers *et al.*, 2010) and is extremely important for blackberry, especially when it is grown in a subtropical area. The yield of 'Tupy' was higher than the yield of 'Xavante' during both crop seasons; however, when both cultivars were evaluated in temperate regions of South America, they had nearly similar production levels (Antunes *et al.*, 2010), which suggests that climate plays a key role in the adaptation of cultivars.

TABLE 5. Means of production per bush and yield of 'Tupy' and 'Xavante' blackberries, seasons 2013 and 2014.

Cultivars	Production (kg bush ⁻¹)		Yield (kg ha ⁻¹)	
	2013	2014	2013	2014
'Tupy'	0.8 ± 0.2*	1.7 ± 0.2*	2,953.5 ± 616.9*	5,561.1 ± 577.5*
'Xavante'	0.5 ± 0.1	0.5 ± 0.1	1,639.3 ± 227.5	1,539.9 ± 283.4

Student's test for independent samples with homogeneity of variances verification with means ± standard deviations.

*: significant at $P < 0.05$.

The yield of the 'Tupy' blackberry increased over the two growing seasons, a finding that is similar to that reported by Antunes *et al.* (2000), who evaluated 'Tupy' in a temperate region and observed that the production increased over three consecutive years. The good yield obtained in the first two seasons and the future prospect of a higher yield may encourage growers to cultivate these blackberry cultivars throughout new subtropical areas, which are locations that currently depend on imports to offer this fruit to the local market. Even 'Tupy' had presented higher yield and better fruit quality, the spineless characteristic of 'Xavante' makes it an interesting cultivar, especially due to its easy way to manage. On the other hand, although the climate conditions during the season could have influenced yield, the age of the plants was mainly responsible for the lower yield in 2013 because the plantings in this study were established at end of 2012 and fruits were harvested in following two production seasons. The quick onset of berry production was due to earlier completion of juvenile stages with perennial fruits, such as citrus, pome and stone fruits (Hackett, 1985), which take up to four years to begin production. The cost of establishing a blackberry field is directly influenced by lower juvenile periods, giving early returns with low inputs, including low cost of planting and minimal maintenance requirements.

Regarding the distribution of cumulative yield (%) in 2013, a clear difference was observed between the cultivars. 'Xavante' blackberry began production earlier in the season than 'Tupy', and yield was equally distributed throughout season. 'Tupy' had higher yield accumulation in a shorter production season from the end of November to mid-December; however, both cultivars were harvested on the same dates (Figure 1).

During the 2014 season, the difference of accumulation of yield between cultivars was still evident, in which 'Xavante' blackberry maintained its high early yield accumulation and the 'Tupy' maintained the later start of production and higher accumulation towards the end of the season (Figure 2).

'Xavante' blackberry started producing earlier than 'Tupy', with a gradual and consistent increase in the percent yield accumulation. The production period of 'Tupy' began later, and 'Tupy' had lower yields during the first four weeks and higher percent yield accumulation at the end of the season. This clearly indicates the potential for the use of both cultivars in a subtropical area to address the requirements of both the fresh and the processed industries for optimum commercial development of blackberries.

Inconsistent weather conditions, *e.g.*, temperature and rainfall, may induce earliness or delay the initiation of blackberry production over the years of production. However, good blackberry production is more consistent in cultivars with good tolerance to high temperature during flowering under subtropical conditions (Takeda *et al.*, 2002). Lower temperature during the winter of 2013 caused 'Tupy' blackberry to begin production later than 'Xavante'. In 2014, the winter period was somewhat shorter, causing 'Xavante' to start yield a week later than in 2013. However, the differences in yield became less towards the end of the production season over time, indicating that the cultivars respond differently to the climate conditions, causing 'Xavante' to produce earlier than 'Tupy'. Blackberry cultivars that start flowering later in the spring are less susceptible to damage by frost, resulting in more consistent yields (Lewers *et al.*, 2010). On the other hand, early cultivars can result in early fruiting in the absence of frost and have the potential to produce fruits during a longer period, resulting in a greater yield.

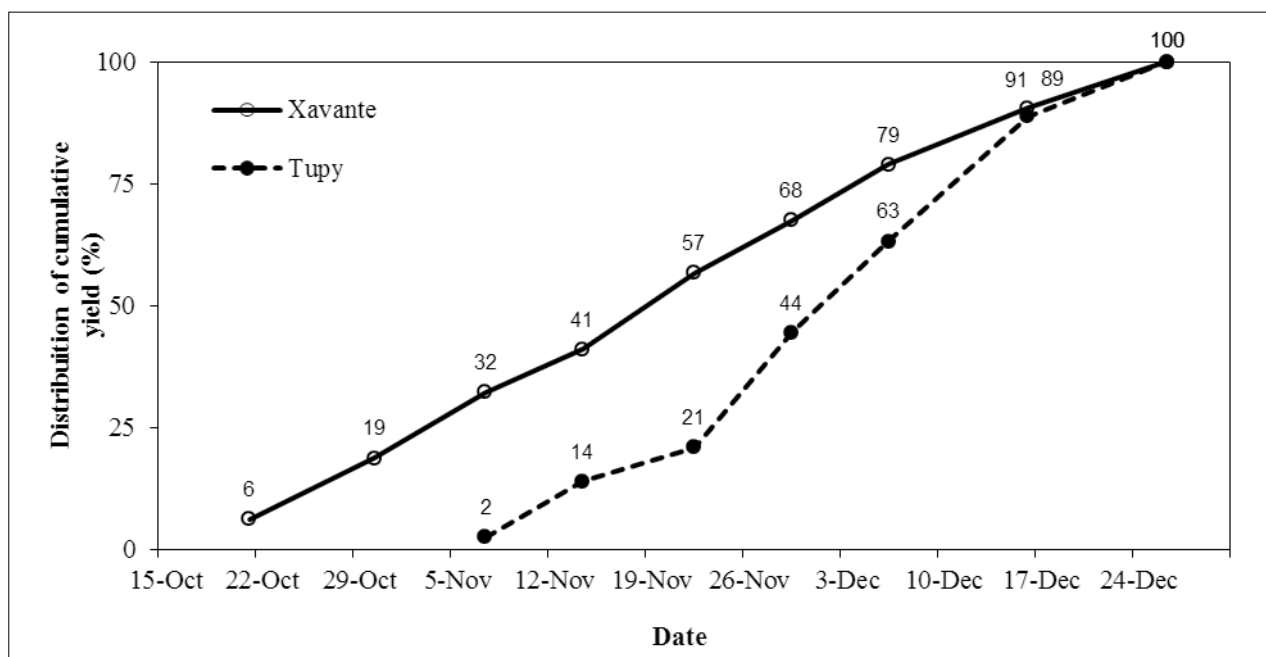


FIGURE 1. Percentage distribution of cumulative yield of 'Tupy' and 'Xavante' blackberries. Season 2013.

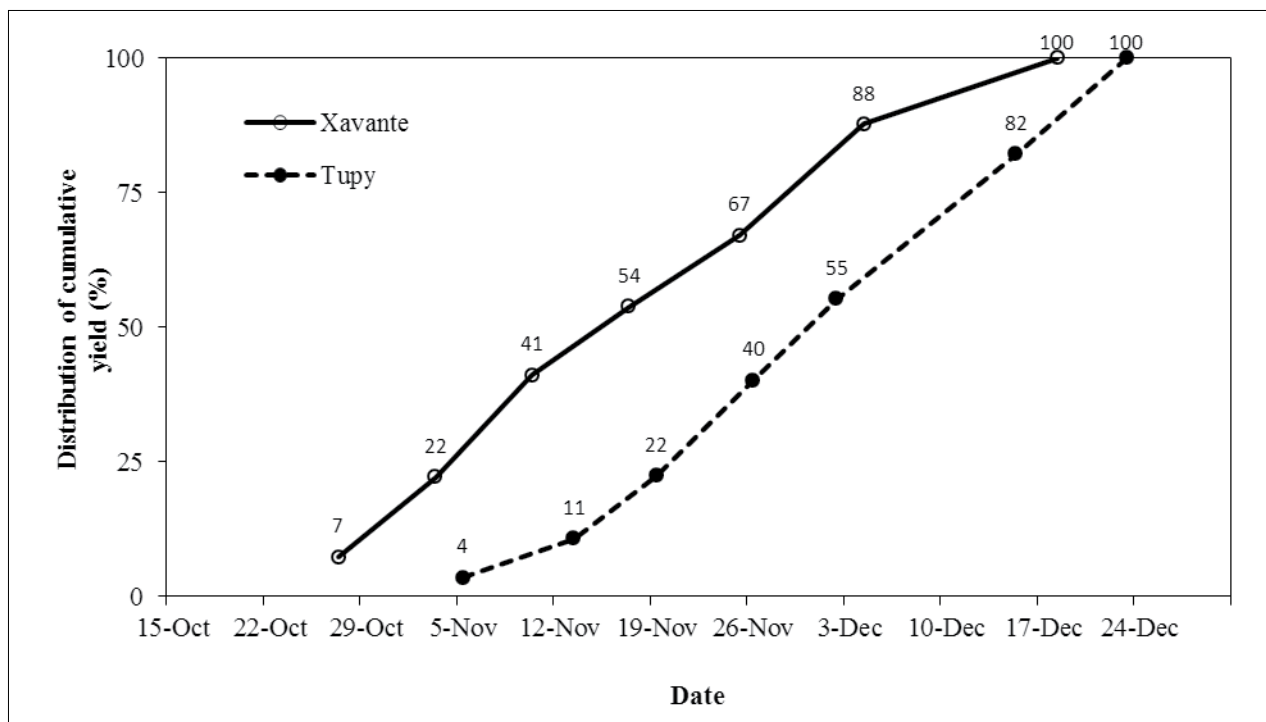


FIGURE 2. Percentage distribution of cumulative yield of 'Tupy' and 'Xavante' blackberries. Season 2014.

It is important to state that blackberry cultivars under subtropical conditions started producing earlier than in some temperate regions of the southern hemisphere (Antunes *et al.*, 2010) due to low frost risk and early increases in temperature in the spring. Thus, the use of these cultivars is a profitable option in extended geographical areas with extreme temperature events. Moreover, the use of these cultivars may allow growers to produce fresh blackberries in subtropical areas to fulfill the demand for fresh market of blackberries, and obtain good prices with an expanded date of harvest once most commercialized fruits (fresh and frozen) are supplied from temperate areas. This has an import-

ant market impact because it makes commercialization of blackberries possible during periods of low supply (Hussain *et al.*, 2016).

Under subtropical conditions, both 'Tupy' and 'Xavante' were free of any serious cane, leaf or berry disease, and neither cultivar showed any physiological disorders, such as drying of canes, berry shrivel, and dropping of flowers. Therefore, these cultivars are strong candidates for the organic production, an increasing market trend. Due to mild winter conditions, no winter injuries were observed for either cultivars. The agroecological management used in this trial involved regular manual weed control without the use

of synthetic inputs and was very promising for both blackberry cultivars in the subtropical area. Moreover, consumers are increasingly demanding organic products, providing a great opportunity for growers to exploit this segment more intensively.

Although 'Xavante' presented lower yields than 'Tupy' when grown under subtropical conditions, the good chemical properties and the earliness of berry production make this cultivar appropriate for large-scale production with early harvest and an extended harvest period under mild winter climate. Moreover, the spineless canes of 'Xavante' also makes this cultivar a good option for machine harvesting, a developing production option when labor for harvest is scarce or expensive. Besides, production of 'Xavante' is also a good option for small-scale growers and domestic use. 'Tupy' had overall good adaptation; the fruits were relatively large-sized with optimum total soluble solids contents, high yields and a higher percent of yield accumulation towards the end of the harvest season. Therefore, this cultivar grown in subtropical conditions can be a good option for growers to commercially produce fruit for fresh consumption, both for local sales and for distant markets. In addition, 'Tupy' is a good option for the processing industry due to the good quality attributes and its high yielding, fulfilling the demand of processing industry. The adaptation of these cultivars in regions to mild winter conditions may stimulate growers to produce blackberries with fewer limitations than in temperate regions, where adverse winter conditions force them to use more costly practices, such as different protection techniques, for growth and development of blackberries.

Conclusion

The good adaptation of 'Tupy' and 'Xavante' blackberries to subtropical areas allows growers to easily produce fresh fruit using agroecological management without synthetic inputs. This allows for an early harvest within approximately two months and an expanded harvest season from late October to late December to fulfill the market demand for fresh consumption.

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Resúmen

Desempeño de las moras 'Tupy' e 'Xavante' bajo condiciones subtropicales.

Introducción – Un interés creciente en el consumo de mora en todo el mundo exige una mayor producción, tanto para el consumo en frescos y procesados. El cultivo de mora en condiciones subtropicales puede extender el área de producción en todo el mundo mediante el uso de cultivares de alto rendimiento. El objetivo de este trabajo fue evaluar el desempeño de las moras 'Tupy' e 'Xavante' bajo condiciones subtropicales, para tornar disponible cultivares con mejor rendimiento y adaptación a las condiciones de bajos insumos. **Materiales y métodos** – El experimento se realizó en la Estación Experimental de la Universidad Estatal de Londrina, PR, Brasil, durante dos temporadas consecutivas, 2013 y 2014. Las variables evaluadas fueron: longitud, diámetro, peso de los frutos, sólidos solubles totales (SST), acidez titulable (AT), relación SST/AT, pH del zumo, color, antocianinas y polifenoles totales de las bayas, rendimiento y la distribución porcentual de rendimiento acumulado. **Resultados y discusión** – Cuanto las características físicas de los frutos y rendimiento, 'Xavante' presentó promedios más bajos que 'Tupy', pero presentó buenas características químicas y más temprana distribución porcentual de rendimiento acumulado. 'Tupy' presentó frutos de gran tamaño con óptimos SST y pH, color atractivo, alto rendimiento y mayor distribución porcentual de rendimiento acumulado hacia finales de la cosecha. La producción de estos cultivares en condiciones subtropicales puede ser una buena opción para los productores para tornar disponible comercialmente frutos para el consumo en fresco y procesados debido al buen rendimiento y a los óptimos atributos de calidad. **Conclusión** – La buena adaptación de 'Tupy' e 'Xavante' en zonas subtropicales permitirá a los productores a producir fácilmente moras frescas bajo el sistema agroecológico sin insumos sintéticos. Eso permite una cosecha temprana para atender a la demanda del mercado en acerca de dos meses, con fecha ampliada de la cosecha, desde finales de octubre hasta finales de diciembre.

Palabras-clave

Brasil, pequeños frutos, *Rubus* spp., condición de cultivo, características agronómicas, rendimiento agrícola