



## THE BLACKBERRY BREEDING PROGRAM OF “EMBRAPA CLIMA TEMPERADO”: AN UPDATE †

### [EL PROGRAMA DE MEJORA DE BLACKBERRY DE “EMBRAPA CLIMA TEMPERADO”: UNA ACTUALIZACIÓN]

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#### SUMMARY

**Background:** In terms of breeding perennial plants, the Embrapa's blackberry breeding program is relatively recent. It started between the end of the 1970s and beginning of the 1980s with a very limited number of cultivars plus a fairly good number of seeds from hybridizations made at the University of Arkansas, USA. **Objective:** this paper aim to present, in a summarized way, the current stage and recent achievements regarding the top priorities of the breeding program **Methodology:** Controlled hybridizations is the main method used and adaptation to mild winters conditions besides a higher ratio (sugar/acid contents) are among the main objectives. **Results:** Other objectives include high productivity, large size and firm fruits, good post-harvest conservation, erect, thornless canes and harvest period at different time of ‘Tupy,’ the most important one, in Brazil. **Implications:** It is believed that in the coming years, the Brazilian market will learn to like fresh blackberry, mainly considering the release of ‘BRS Cainguá’ and others that hopefully will follow. **Conclusion:** The present status of the program and achievements related to the main goals are discussed. Advanced selections with potential to become a future cultivar are briefly described, emphasizing next probable releases.

**Keywords:** *Rubus*; cultivars and selections; ratio sugar/acid; thornlessn.

#### RESUMEN

**Antecedentes:** El programa de mejora Genética de zarzamora en Embrapa, puede ser considerado relativamente reciente si se compara con otras especies fructíferas perennes. Empezó en fines de los años 70 e inicio de los 80, con un pequeño número de cultivares y un gran número de semillas obtenidas en cruces realizados en la Universidad de Arkansas, USA. **Objetivo:** Este artículo presenta una actualización del estado del programa, como se ha desarrollado, sus objetivos y sus resultados. **Metodología:** Hibridaciones controladas son el método usado y adaptación a condiciones de bajo frío en el invierno y una proporción más alta (azúcar/acidez) están entre las prioridades. **Resultados:** Otros objetivos incluyen productividad, tamaño y firmeza de las frutas, conservación post-cosecha, cañas erectas y sin espinas y período de cosecha diferente de la variedad ‘Tupy’, la más importante en Brazil. **Implicaciones:** En el futuro tenemos una perspectiva que el mercado brasileño tiende aceptar mejor zarzamora fresca/natural, en consideración a el lanzamiento del ‘BRS Cainguá’ y otros que pueden ser liberados. **Conclusiones:** El artículo describe la situación actual del programa en relación con los objetivos planteados, así como, una breve descripción de variedades con potencial para desarrollar nuevos cultivares en un futuro, enfatizando los próximos probables lanzamientos.

**Palabras clave:** *Rubus*; cultivares y selecciones; relación azúcar/ácido; ausencia de espinas.

#### INTRODUCTION

The blackberry belongs to the genus *Rubus*, Rosaceae family. The *Rubus* genus presents forms of sexual and asexual reproduction, having a basic number of chromosomes equal to 7 (Jennings, 1995). The

occurrence of polyploidy, agamospermy (seed formation without sexual reproduction) and interspecific hybridization makes the taxonomy of the group quite complicated (Alice, 2002).

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Despite the existence of wild types in Brazil, a research and breeding program did not start in the country before the 1970's, when a small variety collection from the University of Arkansas, USA and a large number of seeds from controlled crosses made in the same University, were introduced by the Experiment Station of Pelotas (EEP) (Antunes *et al.*, 2014; Raseira and Franzon, 2012), initially as a demand of a processing industry of Pelotas, aiming to produce canned blackberries in syrup. However, before that time, there was some berry cultivation and processing (mainly raspberries) near the area of Campos do Jordão, in São Paulo State.

The introduced collection of cultivars, later enriched with pollen and seeds from other origins, was established on a research area of the EEP (presently part of the Embrapa Clima Temperado) and soon propagated and planted in a private land belonging to the mentioned industry and located in Canguçu, which is among the counties with largest number of small properties. Thus, the blackberry seemed to be a good option for those small growers.

During a few years, that industry processed the fruits in syrup without sugar addition, making a dietetic product, and then stopped. However, the basic material was already established and the research had started, in Brazil. The first cultivars known in the world, were the result of a massive and natural selection and, as a result 'Lawton' and 'Dorchester', were introduced for cultivation, in 1850. One of the first planned genetic breeding programs was conducted in California by Judge Logan, in the 1880s (Jennings, 1981). Nowadays, the blackberry has become a common fruit in the markets, particularly in North America and Europe, not only due to the improved cultivars, developed by breeding programs that have followed Logan's program, but also due to the functional and nutritional qualities of these fruits and the relative ease of cultivation and plant rusticity. In 2005, the area of blackberry in the world was already 25 thousand hectares. World production was 140,292 tons, with the United States, Mexico, China and Serbia as the main producing countries (Strik, 2007).

Another positive characteristic of this species is its adaptation to the organic production system. In 2016, there were already 181 certified organic blackberry properties, in the United States, totaling 971 acres (USDA, 2017). In Brazil, the area cultivated with blackberry was 250 hectares in 2005, (Strik, 2007) and by 2014, it had doubled (Antunes *et al.*, 2014). Although the exact data is not available, it is believed that today it has surpassed 1000 hectares and the cultivation extends not only in the South and Southeast of Brazil, since it is already found in Chapada Diamantina, in the Northeast region.

Breeding program - the blackberry research started in Pelotas, in 1972, therefore just before Embrapa was created (where it was then, the Experimental Station of Pelotas - EEP). This beginning came with the introduction of germplasm donated by Dr. James N. Moore, University of Arkansas (U of A), USA. Plants were asexually propagated and the seeds which came from Dr. Moore's program were scarified and kept in cold chamber with humidity until germination started. Then they were planted and seedlings were evaluated.

In 1982, the first 75 selections were ready to either be further tested or used in new hybridizations (Antunes *et al.*, 2014; Raseira and Franzon, 2012). A few years later, plants of another *Rubus* species, from Uruguay were introduced (Raseira and Antunes, 2004). With the small introduced cultivar collection and the obtained selections, a blackberry breeding program was started. Over the years it was enriched with pollen received from Arkansas (donation by Dr. John Clark), seeds donated by Dr. Chad Finn, USDA Oregon and also by Jorge Soria (Instituto Nacional de Investigación Agropecuaria, INIA, Uruguay) and several crosses were made. As a result of this work, the following cultivars were released: Ebano, in 1981 (Bassols and Moore, 1981); Negrita, in 1983 (it was never cultivated on a large scale and became obsolete); Tupy and Guarani, in 1988 (Santos and Raseira, 1988), Caingangue, in 1992 (Raseira *et al.*, 1992); Xavante, in 2004 (Moore *et al.*, 2004), BRS Xingu, in 2015 (Embrapa, 2015) and BRS Caingua, in 2019 (Raseira *et al.*, 2020), which is indicated for fresh market.

'Tupy' - low chill cultivar released by Dr. Alverides Santos, who was the leader of the blackberry breeding program for nearly 20 years - is still the most important in Brazil, with the largest planted area among them. It is also important in other countries with mild winters. Two years after its release, this cultivar was taken to Mexico and due to the quality of its fruits and its adaptation to a cultivation system that allowed to schedule the harvest season, this cultivar occupied between 6500 to 8000 ha in the Central part of Mexico, in 2013 (Clark and Finn, 2014), placing that country as the world's second largest producer. Most *Rubus* species have biannual stems, which require a period of dormancy before fruiting (Daubeny, 1996). Thus, they need cold accumulation during the winter to overcome dormancy and as a consequence, the priority of the program was, initially, to develop selections and cultivars adapted to mild winter regions, with good level of disease resistance and high yield of firm, large fruits. As the program progressed, new objectives were added to these. It was observed that although the fruit is excellent for jams, juices and sweets, it would not have good acceptance for fresh consumption, as it does not have the sweetness which is the preference of most Brazilian consumers (Raseira and Franzon, 2012).

The *Rubus* plant growth habit varies from erect to prostrate, and they may or may not have thorns. So, the development of selections and cultivars with erect growth habit and thornless canes became more important, mainly due to facilitating handling and harvesting. In the last decade, with the occurrence of high temperatures during flowering and fruit development, also heat tolerance (Zanandrea *et al.*, 2011) became part of the objectives. In addition, aiming to include in the Brazilian culture the habit of consuming blackberry as fresh fruit, besides flavor it is necessary that the fruits have good appearance, color, brightness, uniformity and good post-harvest conservation.

The harvest season, which is presently concentrated in a few weeks, is another limitation for this species expansion and commercialization. In this regard, in addition to seek for earlier or later cultivars than cultivar Tupy, the search for the development of primocane cultivars, which can produce in the fall, has assumed a relevant role. Moreover, the fact that they can produce before the canes pass through the winter provides the possibility of cultivation in areas with little or no chilling accumulation in the winter. There are some management techniques, notably pruning, which combined with the use of phytohormones allow - depending on the cultivar and climatic conditions - to produce off season. However, they increase the production costs and go against the consumers preference for healthier products (without chemicals). Besides that, in places with winter temperatures below 11 or 14°C, the plant development is restricted during the months of June to August in Southern Hemisphere.

The objective of this paper is to present, in a summarized way, the current stage and recent achievements regarding the top priorities of the breeding program from Embrapa Clima Temperado.

## MATERIAL AND METHODS

### Plant Material

A brief description is provided based on the performance of some genotypes during the period from 2010 to 2018, at the headquarters of Embrapa Clima Temperado (ETA) (31° 42' S, 52° 24' W, 57 m altitude), Pelotas-RS, Brazil.

The classic breeding approach, that is hybridization followed by mass selection based on the phenotype, is used in the program. Seeds from the controlled crosses or, whenever desirable, from open pollinated fruits, are extracted, scarified and submitted to humid cold until the germination starts. They are then, sown in greenhouse and later transplanted to the seedling fields. Seedlings evaluation takes place on the first and second year after their production started. Then yield

per plant and disease incidence, plant growth habit, fruit appearance and flavor, as well as time of ripening are the evaluated parameters. The selected seedlings are identified and, in late autumn or during the following winter, they are transplanted to the collection plot. At the time, root cuttings are taken for propagation, to obtain five plants of each selection for farther evaluations.

In the field collection of cultivars and selections, the following phenological parameters are observed: time of sprouting, beginning and full bloom date, beginning and end of harvest dates. At harvest time, they are first submitted to an evaluation, similar to the one mentioned for seedlings and afterwards, a fruit sample is taken to the laboratory for measurements of fruit length and diameter (in samples of five fruits); average fruit mass (based on 20 fruits); subjective taste evaluation and determination of soluble solids content. Also, all the fruits are harvested to estimate the average production per plant. However, whenever this is not possible (mainly due to labor shortage) a note for yield on a scale 1 (very poor crop) to 5 (excellent crop), is given in the field.

Fruit samples of the most interesting selections, without any apparent defect or injury, are placed in clamshells and left in a cold chamber at 4°C ± 1°C, for two weeks. These samples are observed at the end of the first and second weeks, for color reversion, loss of brightness or fruit degeneration. Fruits of 'Tupy' are used as a standard, for comparison purposes (Marchi, 2019). In a more advanced stage of the evaluation process, samples are taken to the post-harvest laboratory for a more detailed evaluation.

Annually, fruit samples of the interesting selections are frozen for later determination of the ratio, that is, total soluble solids /titratable acidity. The ideal would be to make these determinations with fresh fruit, but due to the accumulation of activities at the time of harvest and coincidence with the harvest of other fruit species, it was decided to do it in January - February.

After observations are made in the Embrapa's collection, for at least three or four harvest seasons, the selections that stand out are taken to observation units in other research institutions or producers who have a partnership contract with Embrapa. When a selection is considered ready to be released as a new cultivar, a meeting is made with researchers and technicians involved with tests and data is compared with established cultivars of the same season for a decision. If the final grade average is superior to the available cultivars, it is decided to release and the morphological and phenological data required for registration and protection procedures are putting together to send to Ministério of Agricultura, Pecuária e Abastecimento (MAPA) for approval and proceeding with the process.

## Data collection

From the obtained phenological parameters the data of beginning of harvest in number of days starting in January 1<sup>st</sup>, and the number of days from beginning of blooming to harvest and full bloom to harvest were analyzed.

The average fruit mass (PMF, grams) determined using an analog scale and based on a sample of 20 fruits, the total production per plant (GY kg plant<sup>-1</sup>) obtained from the harvest of all fruits of a plant; total soluble solids content (SST, %), measured in °Brix using a digital refractometer were also analyzed.

## Statistical analyses

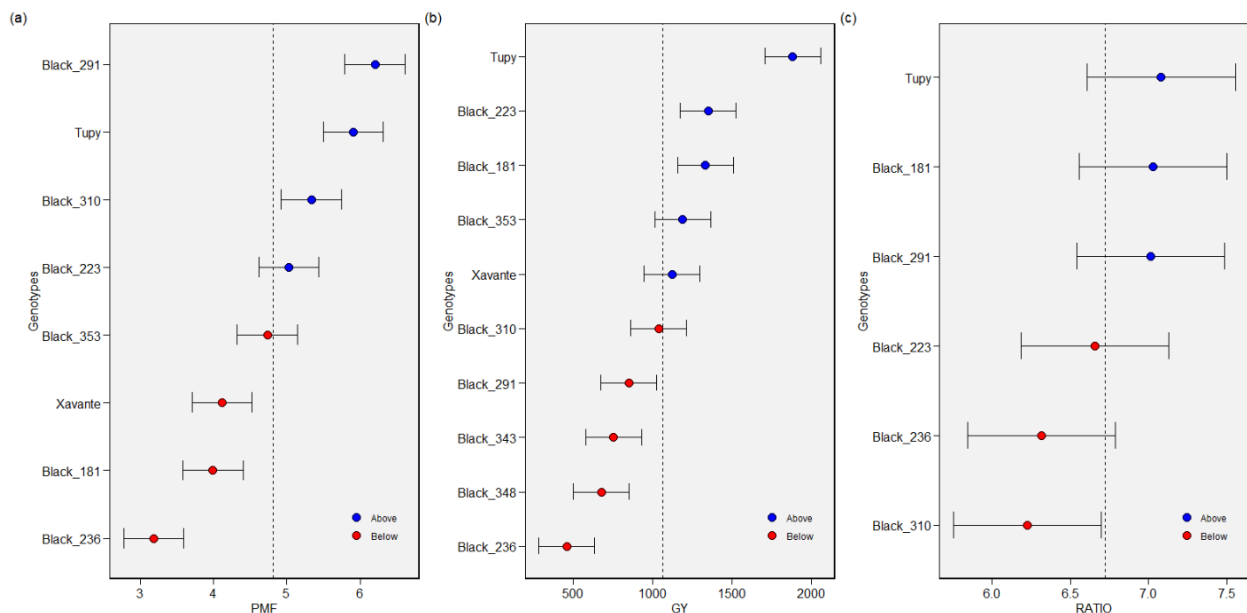
The data were submitted to mixed model analysis, using information of years and genotypes, so we obtained the BLUP and confidence interval (0.95) in the advanced thorny and thornless blackberry selections, individually. The analyses were performed using the package Metan in the R Studio software (Olivoto and Lúcio, 2020). Data regarding to SST trait from the selected genotypes, were analyzed using mixed models. Statistical procedures were conducted using proc mixed in SAS (Statistical Analysis System, version 9.4). From these, BLUP were obtained and then, the genotypic values were displayed in figure.

## RESULTS AND DISCUSSION

Thornless canes – So far, among the released cultivars by Embrapa's breeding program, 'Ébano' and 'Xavante' are thornless. The first has a decumbent growth habit and the second has upright stems. However, a failure characterizes the fruit taste of both, the bitterness and some astringency. It is believed that this goes back to the wild American species *R. ulmifolius*, from which the source for the thornless character, used in the University of Arkansas program (Clark and Finn, 2011) came from, and therefore, also in the Pelotas program. In this species, the thornless character is conferred by a recessive gene. And since the blackberries of the collection are tetraploids, when crossing a homozygous thorny genotype by a thornless one (or vice versa), thornless plants will only be found on second generation and in the proportion of one in each 36 individuals.

After more than 30 years of work and relying on a limited base collection, today the following thornless selections can be highlighted (Figure 1):

- Black 181: obtained from a cross made in 2003, between two thornless cultivars: Arapaho × Xavante. This selection has already produced up to 2.4 kg per plant in 2014, with an average of 4g per fruit. But in general, it produces just over 1kg per plant and the fruits are between 5 and 6g of mass. It should be pointed



**Figure 1.** Thornless selections compared to the standard cultivar Tupy (thorny) and 'Xavante' (thornless). Average fruit weight, PMF in grams (a). Yield per plant GY kg plant<sup>-1</sup>(b). Ratio TSS/acidity % (c). The red dots show that genotype had performance below of overall mean, whereas blue dots, indicate that the genotypes had a performance above overall mean. Line trace is the overall mean of all genotypes.

pointed out that plants of this selection, as all the others mentioned here, are not irrigated and are maintained with short canes since they do not have a support system of wire or any other kind. In figure 1 (b, c), this selection demonstrated values above overall mean.

- Black 236: It is an early ripening selection, but the plants are very susceptible to stem rust, under the conditions of Pelotas. It was obtained by open pollination of a cross between 'Brazos' and 'Arapaho'. Due to the problems with rust, productivity under the tested conditions is low and fruits, are small, around 3g. However, it is still used as parent in the breeding program.

- Black 223: also obtained in the second generation of 'Brazos' × 'Arapaho', it is productive, and the production per plant, conducted with short canes, without support and without irrigation, varied between 1 to 2 kg. But the fruits are small to medium with a mass between 4g and 6g. In figure 1 (b) it is observed that in total yield per plant, this selection had values above overall mean and close to 'Tupy'.

- Black 291: originates from an open pollination of cultivar 'BRS Caingua'. It has low vigorous plants, with light green or yellowish green foliage and short internodes. The fruits have medium mass, usually between 5 and 6g. The positive characteristic is a balanced flavor, with an almost imperceptible bitterness. In figure 1 (a), regarding average weight per fruit, this selection demonstrated values above overall mean and superior to other genotypes (except 'Tupy' and black 310 from which it does not differ). However, its yield per plant is inferior to the overall mean.

From Black 200 to Black 299, there are a total of 15 thornless selections, but with the exception of those mentioned above, the others either produce very small fruits, the productivity is low or have other failures (such as strong bitterness) and are used only in new hybridizations.

In addition to these, there is Black 310 (selections of 300 series, thus more recent) that would have to be tested for a greater number of years and others, such as 348 and 353, of which there is also insufficient data. Also, the selections Black 336, 343, 356 need to be evaluated for some more seasons and Black 371 and 376 must be transplanted in the field collection, in larger number of plants.

So far, Black 181 and Black 223 are perhaps the most promising, since they have fairly good productivity and in an average of three years of evaluation presented a similar ratio to the 'Tupy'. The same ratio tendency was observed for Black 291, whereas Black 236 was inferior. However, considering average fruit weight and yield, Black 181 and 223 produce fruits

with an average fruit weight equal or slightly superior to 'Xavante' (Figure 1a); productions per plant in spite of being inferior to 'Tupy' are similar to that of 'Xavante' (Figure 1b) with the advantage of having better taste, since they have similar ratio of 'Tupy' fruits (Figure 1c), which is superior to cultivar Xavante (data not shown).

Primocane fruiting - As for the primocane fruiting character, the progress of the Embrapa Clima Temperado program has been very slow, mainly because the sources for this character are extremely limited, in the available collection.

Primocane blackberry genotypes produce on the flowering stems (from the spring of the previous year) but also on the primary stems, thus allowing one production in the summer and another in the autumn, or if the producer prefers, it is possible to eliminate summer production and produce only in autumn, that is off season with higher prices. The biggest advantage of this type, in southern Brazil, is the fact that autumn production escapes the normal season and also escapes the peach harvest season, the main temperate fruit species in the south of RS.

Since the characteristic of primocane fruiting is conferred by recessive gene action and blackberries of Embrapa breeding program, as already mentioned, are tetraploids, obtaining a primocane type and, mainly, combined with other characteristics related to fruit productivity and quality, is not as fast as desirable. First, it is necessary to have a good source of this characteristic. The only material in the Embrapa's collection that would be a source was 'Arapaho' which was believed to have at least one gene for primocane. 'Hillquist', one of the main sources of this character in the Arkansas program (Clark, 2008; Lopez Medina *et al.*, 2000) is an ancestor of 'Arapaho' (Moore and Clark, 1993).

In 2005 or 2006, pollen from the cultivar Primojim, (Clark *et al.*, 2007), a primocane cultivar, (therefore with the four genes for this characteristic) was obtained by donation from Dr. John Clark. Several crosses were made with this pollen and with cultivar Arapaho. Finally, in 2010, seedlings were selected that seemed to bear fruit on the primary stems. These were multiplied asexually and were placed in the Embrapa Clima Temperado collection, being then more carefully observed and evaluated. Some of these, despite having produced in the autumn, in reality have fruited in new secondary shoots (lateral stems), which does not classify them as primocane fruiting.

Among the material already evaluated, the selections Black 247 and Black 275 were obtained. However, the selection Black 247 presents, as a flaw, the small to medium fruit size, whose average mass has varied

between 3g and 5g and the productivity is low. Summer production (in floricanes) reached a maximum of 1 kg per plant, but autumn production was not computed. As the plants of this cultivar are being kept without irrigation and their management is well below the recommended, it is quite difficult to estimate its potential under suitable conditions. This selection will be multiplied to be placed in observation units. In the Embrapa collection it produces in the period between April and May, an amount similar to the summer production.

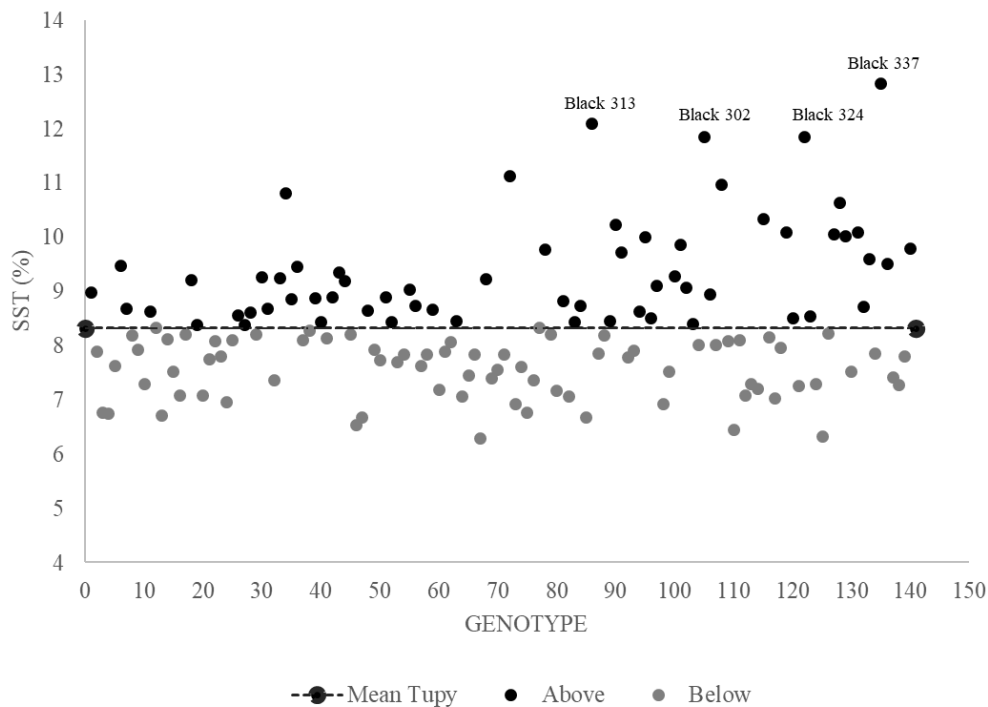
The selection Black 275 has fruits of similar size to the previous one, (or slightly larger) but the plants have greater vigor and production in the flowering stems (summer) exceeds 1kg per plant. The average mass of the fruits is around 4g. However, production on primary stems was not heavy. This selection must also be placed in observation units.

In the most recent selections, such as Black 333, Black 336, Black 365 for example, there were primary stems that flourished but they have to be further observed.

**Fruit flavor-** Over the years, several crossings have been carried out with the objective of improving the fruit's flavor, so that it is in accordance with the preferences of the Brazilian consumers, that is, sweeter and/or less acid. This is also considered a worldwide trend (Clark and Finn, 2008). Several years ago,

attempts were made to hybridize the American cultivars of the collection with *R. erythroclados*, known as white berry and found in the Embrapa Clima Temperado area. This species has flaws such as susceptibility to powdery mildew, large thorns and decumbent canes. However, its fruits are very sweet. Nevertheless, attempts at hybridization with cultivated blackberries were unsuccessful, due to the difference in the ploidy level between species. It would be necessary to make thousands of flowers, hoping that an unreduced gamete would be fertilized by the pollen of the commercial cultivar (or it would fertilize the cultivar) or it would be necessary to duplicate chromosomes in some plant of this wild species. However, it was decided to abandon the idea and use only hybridization with genotypes with a more balanced flavor such as cultivars Cherokee, Caingangue and Tupy, and some selections and pollen, introduced from other programs. Boysenberry and raspberry plants were used too, although they also have the problem of different ploidy levels.

But, in spite of everything, perhaps it was the characteristic flavor where the greatest advance was achieved. At least, half of the selections under testing, have similar or better ratio than 'Tupy'. (Figure 2). Four selections (Black 302, Black 324, Black 331 and Black 337) have a statistically superior ratio to that obtained in fruits of 'Tupy'.



**Figure 2.** Results of the predicted mean values (BLUP) of the total soluble solids trait (%) for 140 genotypes of the blackberry breeding program of Embrapa Clima Temperado, Pelotas – RS, 2020.

The selections Black 265, 268, 196, 232, 327 and 194 were the most acidic and the others were statistically equal to 'Tupy'. The less acidic ones are Black 283, 287 and 292, which, however, did not differ statistically from cultivar Tupy.

### Productivity and fruit size

Productivity has not been a big issue (Fig 3) even under the tested conditions, without irrigation or plant support, with very few exceptions, such as Black 348, that has the desirable character of thornless canes, however has an uneven frutification. Comparing to cultivar Tupy, several advanced selections are either equal or superior to it. We highlight, on these aspects, selections Black 145; Black 178, Black 251; Black 271 and Black 254. In tests with Black 145, where plants were under irrigation and a trellis was used, so plants were taller, the productivity reached 17 to 18 ton/ha in the first production years.

### Time of ripening

Another important objective is the extension of the harvest period, emphasizing late ripening selections, such as Black 216; Black 219 and Black 219 plus some more recent ones – that need to be further tested - such as Black 354, Black 355 and Black 356. Fruit harvests in the months of January and February are easily sold with higher prices. Usually, growers use chemical for defoliation and bud break, to schedule the production. However, if a selection naturally produces at this time, the production cost is reduced and there is a possibility of using organic system.

### Disease resistance

So far, the only disease which causes concerns is rust, mainly in situations where summer pruning is delayed and no fungicide sprays are used. Comparing to cultivar Tupy, most of the advanced selections are less susceptible (ex.: Black 312, Black 331; Black 356, among others) or at least are in the same level. The exception is Black 236 which under Southern Brazil's conditions is very susceptible to the disease.

### Post-harvest conservation

Preliminary tests, using fruits in clamshells under cold storage at 4°C, are performed. Results show different levels of conservation. Black 145 is similar to cultivar Brazos, mainly referring to color reversion. Tests conducted up to 21 days after harvest showed superior performance of cultivars BRS Xingu, BRS Caingua, Tupy, plus selections Black 254 and Black 332 (Figure 4).

### Advanced selections

In addition to the selections previously mentioned, there are other thorny selections that have stood out for specific aspects and are mentioned below (Figure 3):

- Black 145: Origin: Cross of Selection 6/96 × 'Caingangue'. It was highlighted by the productivity and fruit size, both at Embrapa (Pelotas and Canoinhas) and at the observation unit, in Vacaria, RS, where it was tested. It shows higher average fruit weight than fruits of 'Tupy' and similar productivity and good fruit appearance, being its defect the acidic flavor for fresh consumption (Figure 3). However, it would be a great material for the manufacture of jams, which today is still one of the main uses of blackberries, in Brazil. The average fruit mass is generally above 8g (in eight years of observation, the lowest average fruit mass was 6.9g and the highest 8.8g, in the Embrapa collection). The production is over 1.5 kg/plant, on average (Raseira *et al.*, 2012). This selection should soon be released for processing purpose.

- Black 178: Origin: Cross between 'Caingangue' by selection 5/96. The fruits begin to ripen a few days (4 to 5) before cultivar Tupy (Raseira *et al.*, 2012). The plant is semi-erect, it produced around 2.5 kg/plant, in the full productive phase of the plant (Raseira *et al.*, 2012), but the average of several years is inferior to that. The fruits, with small to medium seeds, a sweet-acid flavor with slight bitterness, have good glossiness and post-harvest conservation. However, the ratio (sugar/acidity), on the average of two years, was a little over 5, therefore lower than 'Tupy'.

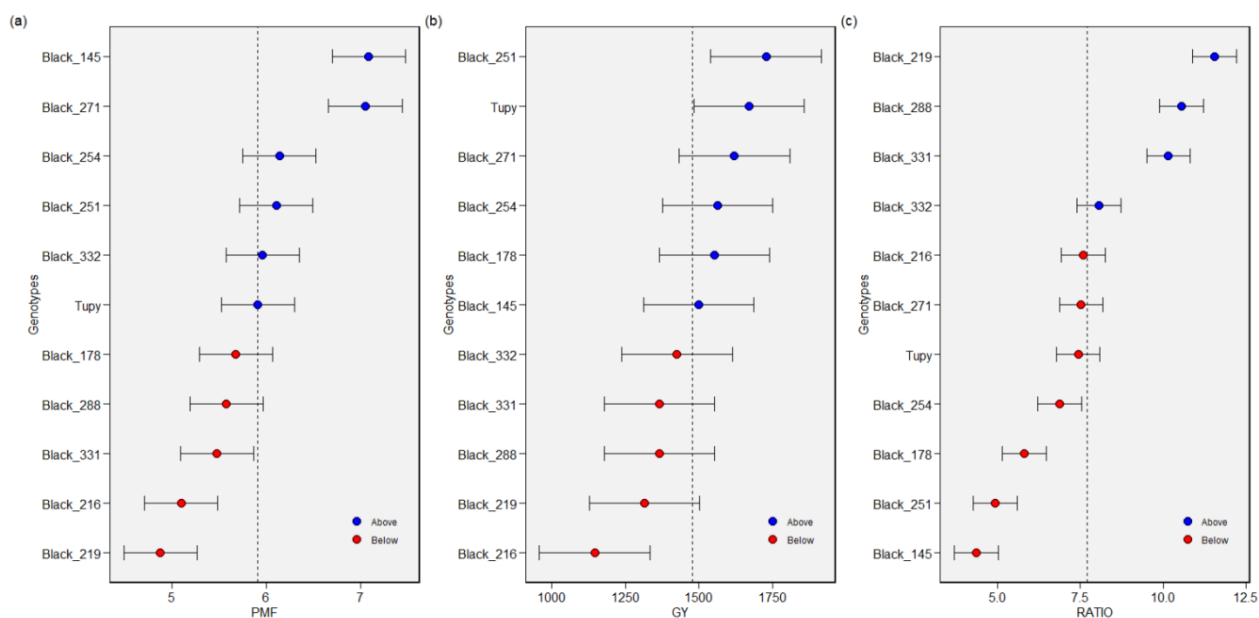
- Black 216: Origin: It was obtained from a hybridization between selection 2/96 × Caingangue. Harvest starts 22 days later than 'Tupy', based on the average dates of 2009 to 2018 (supplementary material), extending the season at least until mid-January. It produces good-sized fruits and its plants are upright. In Pelotas, there was great variability in production, with 500g to 1.3 kg per plant and fruit with a variable mass from 3 to 7g (Unpublished data, Embrapa files). But at the Experimental Station of Vacaria, Embrapa Uva e Vinho, it has had excellent performance and should be released in the coming years, for that region.

- Black 219: Originated from a controlled cross ('Caingangue' × Sel 5/96). The plants are erect, thorny with reddish canes. Its harvest is later than Black 216 and the fruits have a good sugar-acidity ratio, higher than that of 'Tupy'. It has great potential when looking for later maturation than 'Tupy'. Production per plant ranged from 460g in 2018 (perhaps the worst year for all selections) to 1890g/plant in 2014. In six years

observed, only one of them produced fruit with an average mass of 3g, in the others it was always between 4g and 5.5g (Figure 3 c). It is important to highlight that this is a selection of late maturation and without irrigation, which suffers more than the early ones with water stress. Thus, even with lower productivity and fruit weight, both selections Black 216 and Black 219 are interesting to farther extend the harvest, especially if irrigation is used. On the average harvest dates from 2009 until 2018, Black 219 was 33 days later than ‘Tupy’ (supplementary material).

- Black 251: Originated from a cross between cultivars La Campeona × Tupy. It is one of the earliest

selections in ripening and probably the one with lowest chilling requirement. It produced very well in 2018, when there were only 87 hours below 7.2 °C, in the site where the collection is whereas all the other selections produced very little. This selection is highly productive and with good-looking fruits, oblong shape, with an average of 6 to 7g, sweet-acid taste with some bitterness at the end. In Pelotas, the average beginning of harvest is in the second week of November (Embrapa's files). It can be very interesting for subtropical regions since it is only inferior to ‘Tupy’ on ratio.



**Figure 3.** Thorny selections compared to the standard cultivar Tupy (thorny). Average fruit weight, PMF grams (a). Yield per plant, GY kg plant<sup>-1</sup> (b). Ratio, TSS/acidity % (c). Red point demonstrated that genotype had performance below of overall mean, blue points color, indicates that the genotypes had a performance above overall mean. Line trace is the overall mean of full genotypes.

**Table 1. Supplementary material. Comparative dates of beginning of harvest of selections Black 254, Black 216 e Black 219, in relation to cultivar Tupy. Difference in days.**

Harvest	Tupy	Black 254	Difference	Black 216	Difference	Black 219	Difference
2009	17/11			18/12	31		
2010	24/11			14/12	20	15/12	21
2011	18/11	07/12	19				
2012	9/11	27/11	18	23/11	14	12/12	33
2013	19/11	29/11	10	03/12	14	03/12	14
2014	08/11	20/11	12	02/12	24	24/11	16
2015	16/11	01/12	16	01/12	15	14/01	58
2016	14/10	11/11	27	21/11	37	28/11	44
2017	28/10						
2018	10/11	28/11	18	30/11	20	20/12	40



- Black 254: This selection has stood out since its first evaluation. The average fruit weight varies from 6 to 7 g. Maturation begins at the end of November. The soluble solids content varies from 9 to 13 ° Brix (exceptionally there was a year with 7.5 ° Brix). It is similar to the standard cultivar Tupy, however, on the average, the harvest (2011-2018) starts 17 days later than 'Tupy' (Supplementary material Table 1).

- Black 271: It was selected from the crossing of Selection 2/96 by pollen of 'Caingangue' It has plants with short internodes and small thorns. Average to good production 1.2 to 1.7 kg/plant and fruits around 6g of mass. It is similar to Tupy in yield and ratio but superior in average fruit weight. (Figure 3).

- Black 288: It was selected for the first time in 2014, among the seedlings obtained from the progeny of the cross between the cultivars Tupy and Navaho. The production is medium and the fruit has a mass around 5g per fruit. On three years average it had a high ratio (above 11, on average, while the fruits of cultivar Tupy had a ratio just above 7). This is a very interesting selection when aiming the consumption of fresh blackberry fruits in Brazil. Considering only this group, Black 288 has the second highest ratio but did not differ from the Black 219 (the highest) and Black 331, being the three of them significantly higher than the average ratio of 'Tupy' fruits.

- Black 331: Origin: selected among the seedlings of the cross between the cvs. Tupy and La Campeona. The canes have low to medium density of thorns. The fruits are juicy, with good appearance and shine; medium firmness; elongated shape and sweet-acid flavor and slightly bitter taste. The average fruit mass is between 4 to 5g (under the conditions of the Embrapa collection) and the soluble solids content between 10 and 12 ° Brix. At an average of three years, the ratio was 11.87, well above 'Tupy' (7.37). It produces, under the tested conditions, just under 1 kg per plant.

- Black 332: Origin: Cross between the selection Black 158 and 'Caingangue'. The reddish stems are thorny and tend to be semi-erect. The fruits are medium (5g to 6g), oblong, with good shine and firmness. Productivity does not differ from Black 331 but ratio is inferior to it.

More recent selections like Black 352, Black 354, Black 355, Black 356, Black 358 and Black 362 require more years of observation.

## TENDENCIES

It is believed that in the coming years, the Brazilian market will learn to like fresh blackberry, mainly

considering the release of 'BRS Caingua' and others that hopefully will follow.

In the next two or three years, a later cultivar than 'Tupy' should be released, extending the harvest for a few more weeks, as well as a new cultivar thornless probably either Black 181 or 223. All this, combined with the cultivation practices that are being investigated by other research areas, including forced production, will certainly increase interest in this species.

In summary, there are good perspectives among the selections now under evaluation, such as Black 254 and Black 332 in a few years and Black 302, 324 and 327 in a medium period of time, especially if the fresh market commercialization is the target. However, faster progress will depend on greater support for the program, mainly in terms of human resources.

## CONCLUSIONS

Improvements have been achieved regarding fruit flavor and conservation.

Selection Black 145 will soon be released for processing purposes due to its high productivity and fruit size.

A late ripening season genotype will be released in the next couple of years in order to extend blackberry season in Brazil.

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