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CROP SCIENCE

Phenological and productive characteristics of blackberry genotypes grown in an organic production system

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Abstract: Blackberry is a species which has high potential to grow in an organic production system. However, there is scarce information on the behavior of cultivars and selections of this species conducted in an ecologically based system, a fact that makes it difficult to recommend cultivars for this production system. This study aimed to evaluate and characterize the phenology and productive aspects of six blackberry genotypes grown in an organic system, in Pelotas, Rio Grande do Sul (RS) state, Brazil. Evaluation of the following variables was carried out in the three first production cycles (2015-2016, 2016-2017 and 2017-2018): phenology, number of fruits.pl^{-1}, mean fruit yield.pl^{-1}, yield ($kg.ha^{-1}$), mean fruit mass (g) and soluble solid content (° Brix). Regarding phenology, genotype Black 112 was later than the others whereas Black 178 was the most precocious one. In the last year under evaluation, genotypes yielded around 10 $ton.ha^{-1}$, except Black 128 selection, which yielded approximately 6,767 $ton.ha^{-1}$. Genotypes Black 178, Black 112 and Black 145 and both cultivars BRS Xingu and Tupy exhibited potential to grow in an organic production system.

Key words: agroecology, cultivars, small fruits, *Rubus* spp.

INTRODUCTION

Blackberry has drawn the attention of producers and consumers, who have become more and more demanding lately. This fact has been attributed to several factors, such as economic and social ones, nutraceutical characteristics found in the fruit and search for healthier food (Antunes et al. 2014, Farias et al. 2014).

Blackberry bushes adapt well to different regions and climates, from mild winters (from 200 cold hours on) to extremely cold winters (more than 1,000 cold hours at temperatures below 7° C). In Brazil, 250 ha were used for growing blackberries in 2005 (Strik et al. 2007), but the area has increased to about 527.8 ha in 2014, mainly in both South and Southeast regions (Rio Grande do Sul (RS), Santa Catarina, Paraná, Minas Gerais, São Paulo and Espírito Santo states). In the southern region, since productivity of blackberry cultures has reached about 10 ton. ha^{-1}, it has been considered an alternative to diversify production on small family farms, mainly due to low implementation costs, precocious yield (in the second year after cultivation), minimum need for agrochemicals and the possibility of being grown in na organic production system (Broetto et al. 2009, Raseira & Franzon 2012, Antunes et al. 2014, Fagundes 2014).

Changes in people's eating habits, together with the search for healthy food, have increased fruit consumption, mainly fresh ones, provided that they have good quality, practicality and high nutraceutical value, which are characteristics that are easily found in blackberries (Antunes et al. 2014).

The genetic improvement program carried out by the Embrapa Clima Temperado, located in Pelotas, RS, Brazil, has been very important to the development of the blackberry culture in Brazil. It has recently launched commercial cultivar 'BRS Xingu'. The study of the agronomical performance of genotypes in organic production systems enables cultivation to be broaden and directed, so as to support the genetic improvement program in the decision-making process of launching new commercial cultivars (Raseira et al. 2012, Hirsch et al. 2012, Embrapa 2015).

When phenology, yield, fruit quality and incidence of pests and/or diseases in blackberry genotypes investigated, their behavior can be evaluated in an organic production. system and its recommendations. This information is important to farmers because it helps to organize the harvest period and plant management, besides enabling to find genotypes that can provide a period of high fruit supply to the market (Antunes et al. 2010, Raseira & Franzon 2012, Curi 2012).

Cultures that use organic systems, regardless of the species, operate with principles that care for environmental, social and economic issues, besides exerting low environmental impact, prioritizing local agricultural inputs and rejecting application of chemical fertilizers and agrochemicals. As previously mentioned, blackberry bushes adapt well to this system due to their rusticity (Antunes et al. 2010, Leite et al. 2011).

This study aimed at characterizing cultivars and selections of blackberry bushes regarding phenological and productive aspects, in an organic production system, in Pelotas, RS, Brazil.

MATERIALS AND METHODS

The experiment was carried out at the Estação Experimental Cascata (EEC), located in Pelotas, RS, Brazil (31°37'9" S; 52°31'33" W; altitude of 170 m). The climate in the region is humidsubtropical – Cfa, according to Köppen climate classification.

Precipitation is well-distributed throughout the year. Maximum temperatures in summer range from 34°C to 36°C, whereas minimum temperatures in winter range from -2°C and 0°C, and frost may occur. Its soil was identified as Argissoil B horizon. Evaluation was carried out in three production cycles, i.e., 2015/16, 2016/17 and 2017/18.

The experimental area was implemented in October 2014 with six blackberry genotypes (selections Black 178, Black 112, Black 145 and Black 128 and cultivars 'BRS Xingu'and 'Tupy') from the genetic improvement program carried out by the Embrapa Clima Temperado. Spacing was 3.0 x 0.50m, with no tutoring. Since plants were managed in an organic production system, neither chemical fertilizers nor pesticides were used. Fertilization with turkey manure was carried out in the experiment, in the ratio of 5 kg/meter per year.

Phenological evaluation was conducted in agreement with the methodology described by Antunes et al. (2000), considering the beginning of bloom (5% open flowers), full bloom (from 50 to 70% open flowers), beginning and end of harvest of every blackberry genotype. Evaluation started after the winter pruning carried out in August. Phenology was frequently evaluated by observing the visual aspect of the plants.

Harvest periods in the first and second production years ranged from November to January. Fruits were harvested at commercial point, i. e., when they were in the full ripening stage and their color was dark or shiny black (Antunes et al. 2010, Brugnara 2016). Manual harvest took place in the morning and fruits were kept in polyethylene containers (plastic trays) to enable transport and mitigate damage, since blackberries are very sensitive.

Mean production estimated per plant (g.pl^{-1}) was found when the total mass of fruits harvested per parcel was divided by the number of plants. The variable yield (Kg. ha^{-1}) was based on the density of 6,666 plants and was found by multiplying mean weight by plant and density. The number of fruits yielded per plant was calculated when the total number of fruits harvested per parcel was divided by the number of plants in every treatment.

The experiment had a randomized complete block design, with three replicates and eight plants per parcel. Data on variables under investigation were submitted to the analysis of variance and then compared by the Tukey's test at 5% significance, by the statistical program Assistat®.

RESULTS AND DISCUSSION

The beginning of bloom in the 2016-17 production cycle took place at the end of September (Table I). Both cultivar BRS Xingu and selection Black 145 started bloom earlier than the other genotypes (three days before). Full bloom was firstly reached by selections Black 178 and Black 145 and by cultivar BRS Xingu (before the second

Table I. Phenological characteristics of six blackberry genotypes in an organic production system in 2016-2017 and 2017-2018. Pelotas, RS, Brazil, 2017.

Genotypes	Beginning of bloom	Full bloom	Beginning of harvest	End of harvest	Harvest period (days)
2016-2017					
Black 178	26/Sep	14/Oct	11/Nov	12/Jan	61
Black 128	26/ Sep	21/ Oct	11/Nov	03/Jan	52
Black 112	26/ Sep	29/ Oct	11/Nov	12/Jan	61
Black 145	23/ Sep	14/ Oct	11/Nov	12/Jan	61
'Xingu'	23/ Sep	14/ Oct	11/Nov	08/Jan	56
'Tupy'	26/ Sep	24/ Oct	11/Nov	12/Jan	61
2017-2018					
Black 178	18/Sep	27/Sep	26/Oct	01/Feb	98 days
Black 128	23/Sep	30/Sep	16/Oct	30/Jan	106 days
Black 112	04/Oct	22/Oct	13/Nov	05/Feb	84 days
Black 145	20/Sep	29/Sep	26/Oct	23/Jan	89 days
'Xingu'	27/Sep	30/Sep	03/Nov	25/Jan	83 days
'Tupy'	02/Oct	13/Oct	06/Nov	30/Jan	85 days

fortnight in October). Selections Black 128 and Black 112 and cultivar Tupy only reached full bloom at the end of October, i.e., from 7 to 15 days after genotypes whose bloom was more precocious. Harvest of fruits from all genotypes began in the first fortnight in November and ended at the end of first fortnight in January. The harvest period ranged from 52 to 61 days. Selection Black 128 had the shortest harvest period, followed by 'BRS Xingu' (56 days) and selections Black 178, Black 112 and Black 145 and cultivar Tupy (61 days).

In the first year under phenological investigation (Table I), selection Black 178 exhibited precocious behavior, since bloom began in the second fortnight in September, followed

by selection Black 145, whose bloom started two days later. Selection Black 112 had late

behavior and bloom started in October. Besides, in the 2015-16 production cycle, plant behavior, regarding the beginning of bloom, was more uniform among genotypes than inother cycles. However, in the second year under phenological investigation, variation was higher than in the previous year. It may be associated with climate conditions, mainly to cold hours (Table II), whose variation was high. In 2016, there were 150 more cold hours than in 2017. But phenology does not depend only on cold hours. There are also other factors, such as management, characteristics that are inherent to the species and/or variety, plant maturity and climate factors, that contribute to it (Curi et al. 2015, Hussain et al. 2017). Table III shows mean precipitation, in ml, at the Estação Experimental Cascata (EEC), from January to December in the three years under analysis (2015, 2016 and 2017). This information was provided by the laboratory of agrometeorology that belongs to the Embrapa Clima Temperado. Precipitation varied throughout these three years, but there was less volume of rain in 2017, mainly from September to December, than in the other years.

Table II. **Data on cold hours (below 7.2°C) from 2015 to 2016, at the Estação Experimental Cascata (EEC) Pelotas, RS, Brazil.**

Year	Cold hours
2015	219
2016	348
2017	198

Source: Agrometeorology laboratory Embrapa-Sede.

Temperatures also varied in the three years under analysis (Figure 1). Mean maximum and minimum temperatures in most months in 2017 were higher than the ones in 2016. In September, October and December, maximum temperature was above 20°C, while the minimum one was above 10°C. In the three years, mean temperatures from January to December did not exceed 30°C. The beginning of harvest in the 2017-18 production cycle showed variation among the genotypes, i. e., selections Black 178, Black 128 and Black 145 had early harvest in October. In the case of cultivars BRS Xingu and 'Tupy', beginning of harvest occurred in November, along with selection Black 112, which was the latest one, i.e., 28 days by comparison with the first harvested genotype (selection Black 128).

Harvest was carried out until the beginning of February in the 2017-18 crop. Harvest periods of all genotypes ranged from 83 to 106 days. The period of cultivar BRS Xingu was 83 days – the shortest one – whereas selection Black 128 had the longest one, i.e., 106 days.

This variation was also observed by Antunes et al. (2000) in the case of cultivar Tupy in Poços de Caldas, Minas Gerais state, since beginning of bloom took place in October. Results of

Table III. Monthly precipitation, in ml, from 2015 to 2017 at the Estação Experimental Cascata (EEC). Pelotas, RS, Brazil.

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	199.80	85.00	71.30	49.20	199.40	151.80	217.30	102.60	277.00	266.70	176.90	203.30
2016	174.70	126.60	275.30	302.0	117.47	28.63	137.35	277.96	181.78	178.54	177.47	186.60
2017	172.15	254.40	164.99	124.59	343.76	181.43	55.50	292.02	135.83	146.00	66.51	28.41

this cultivar were similar to the ones found in Pelotas.

The beginning of harvest in this cycle varied a little, i. e., it occurred in October, in the cases of selections Black 178, Black 145 and Black 128, and in November, in the cases of cultivars 'BRS Xingu' and 'Tupy' and selection Black 112.

According to Antunes et al. (2010), this variation in phenology may be attributed to the genetics of every genotype, climate conditions (temperature, precipitation, cold hours) and management. For instance, cold hours are important to blackberry bushes since they are needed to end dormancy, start budding, get uniform bloom and, finally, reach good yield.

In the first evaluation period, 2015/2016, there were significant differences among blackberry selections and cultivars in the following variables: number of fruits, mean fruit mass, yield per plant and total yield (Table IV).

In the 2015-2016 crop, selection Black 178 stood out with 178.1 fruits.pl^{-1}, but did not differ statistically from cultivar 'BRS Xingu', with 108.2 fruits.pl^{-1}. The number of fruits ranged from 33.5 to178.1 fruits.pl^{-1} and the fact that it was the first crop somehow corroborated the lack of yield uniformity.

Regarding yield of fruits per plant, in g, this crop showed that selection Black 178 and cultivar BRS Xingu had the highest values, i. e., 1,164.3 g.pl^{-1} and 810.0 g.pl^{-1}, respectively.

Although selection Black 178 did not differ from cultivar BRS Xingu and selection Black 112, its yield was significantly higher than the ones of cultivar Tupy and selections Black 145 and Black 128. In fact, selection Black 128 yielded 899 g.pl^{-1} less than the genotype that yielded the most, i.e., selection Black 178, which yielded 507.7 g.pl $^{-1}$ in the first year, in November.

The highest blackberry yield in the first crop was exhibited by selection Black 178 – 7,844.5 kg.ha^{-1} – which differed significantly from the others, except 'BRS Xingu' – 5,400 kg.ha^{-1}. Lowest yields were found in both selections Black 128 (1,768.9 kg.ha^{-1}) and Black 145 (2,431.1 kg.ha^{-1}) and in cultivar Tupy (2,673.3 kg.ha^{-1}).

Selection Black 128 yielded 22.55% less than selection Black 178, a difference that means around 6 ton. ha^{-1}.

Oliveira et al. (2017) studied some blackberry cultivars in Minas Gerais state and also found differences in their productive behavior. They attributed this variation to management and adaptation of every genetic material, but highlighted climate conditions, mainly temperature, in the production period.

Concerning the variable mean fruit mass, there was statistical difference in the first crop, i.e., fruits ranged from 6.1 g to 7.9 g, in the cases of selections Black 145 and Black 128, respectively.

In the second crop (2016-2017), the performance of selections and cultivars was

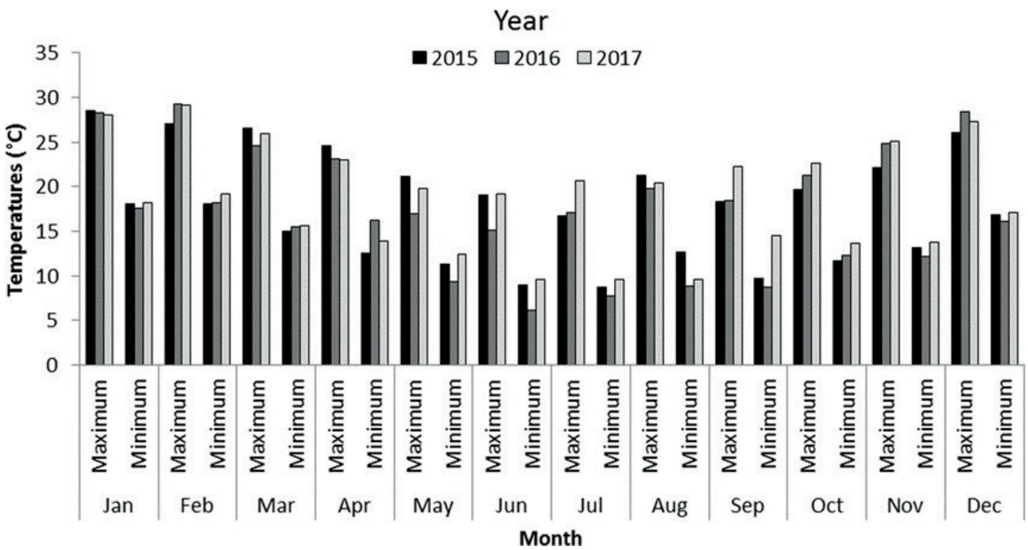

Figure 1. Data on maximum, minimum temperatures (°C) at the Estação Experimental Cascata (EEC) in the years 2015, 2016 and 2017. Pelotas, RS, Brazil.

similar to the one found in the first cycle under evaluation. Numbers of fruits obviously increased a lot in all genotypes under investigation (Table IV). However, in the second crop, selection Black 145 yielded, on average, 313.6 fruits per plant, which did not differ significantly from selection Black 178. In the first crop, the lowest values of numbers of fruits per plant were also exhibited by selections Black 128 and Black 112 and by cultivar Tupy, but they did not differ significantly from 'BRS Xingu'.

In the second production cycle, genotypes under evaluation did not show any significant differences in values of mean fruit mass, which ranged from 3.23 to 4.65 g.

In addition to yield, the ripening period is an important factor that must be observed in materials from improvement programs so as to schedule production (Raseira & Franzon 2012). In the first year, harvest started on November 19th, 2015 and ended on January 28th, 2016, when production was very low, about 20 kg/ha, an amount that did not make it viable (Figure 2a). The harvest period lasted 67 days. Selection Black178 reached its peak at the beginning of harvest, in the second fortnight in November, while 'BRS Xingu' had its peak at the beginning of December. Selection Black 178 and cultivar Tupy exhibited another production peak at the end of December, but it decreased in the next harvests. Selection Black 112 stood out because it got the highest yield from January on, whereas selection 128 had constant low yield throughout harvest, by comparison with the other genotypes.

Regarding yield distribution in the second year (2016-17), once again, Black 178 had the highest value, i.e., 439.29 g.pl $^{-1}$ in November (Figure 2b).

Harvest started on November 11th, 2016 and ended on January 12th, 2017, when production was very low, on average 14.6 kg/ha, an amount that did not make it viable. The harvest period lasted 59 days, on average. Selection Black 178 and cultivar BRS Xingu had their peaks in the second fortnight in November, whereas selection Black 145 reached its peak at the beginning of December. Cultivar Tupy has its production peak at the beginning of December, but it decreased in the following harvest periods. Selection Black 128 reached it at the end of November, but production decreased afterwards.

Concerning yield in the 2016-2017 cycle, genotypes differed statistically. Selection Black

Table IV. Mean number of fruits. pl^{-1}, mean fruit mass (MFM), yield per plant ($g.pl^{-1}$) and yield $kg.pl^{-1}$ of blackberry genotypes grown in an organic production system in 2015/16, 2016/17 and 2017/18 crops at the Estação Experimental Cascata (EEC). Pelotas, RS, Brazil 2017.

	Number of fruits	Mean fruit mass (grams)	Yield per plant ($g.pl^{-1}$)	Yield ($Kg. ha^{-1}$)
2015-2016				
Black 178	178.11 a	6.5 b	1164.33 a	7844.45 a
Black 128	33.46 b	7.9 a	265.33 b	1768.89 c
Black 112	80.88 b	7.4 ab	598.33 ab	4177.78 bc
Black 145	59.67 b	6.1 b	364.67 b	2431.11 c
‘Xingu’	108.17 ab	7.5 a	810.00 ab	5400.00 ab
‘Tupy’	52.42 b	7.6 a	401.00 b	2673.34 c
2016-2017				
Black 178	289.77 ab	4.65 ns	1587.38 a	10582.56 a
Black 128	137.22 c	3.88	664.96 b	4433.16 cd
Black 112	170.34 c	4.56	770.47 b	5136.44 bc
Black 145	313.64 a	3.72	1085.84 ab	7238.92 b
‘Xingu’	184.32 bc	3.23	845.08 b	5633.90 bc
‘Tupy’	127.85 c	3.67	467.22 b	3114.83 d
2017-2018				
Black 178	317.92 ns	5.90 ab	2052.61ns	13684.00 ab
Black 128	246.33	5.01b	1015.23	6766.67 b
Black 112	286.05	7.27 a	2083.81	13892.00 ab
Black 145	350.62	6.18 ab	2220.92	14806.01 a
‘Xingu’	373.82	5.31 ab	1570.85	13741.34 ab
‘Tupy’	219.92	6.22 ab	1560.78	10405.34 ab

*** Means followed by the same letter in the column do not differ statistically from each other. The Tukey’stest was applied at 5% probability. Ns – non-significant.**

178 had the highest value (10,582.6 kg.ha^{-1}), whereas cultivar Tupy showed the lowest one (3,114.8 kg.ha^{-1}), even though it was close to values exhibited by selection Black 128 (4,433.2 kg.ha^{-1}).

Blackberry yield may be considered good, since it was about 10 ton.ha $^{-1}$ (Raseira & Franzon 2012), the value provided by selection Black 178 in the second year. Cultivar 'Tupy' yielded 3.114 ton.ha^{-1}, close to the value found by Broetto et al. (2009) who reached 3.02 ton.ha^{-1} with cultivar Xavante in an organic system carried out in Paraná state. Antunes et al. (2010) found higher yield with 'Tupy', i. e., 5.17 kg.ha^{-1}, than the one found by this experiment in an organic system in Pelotas, RS. However, Hussain et al. (2017) found 5,56 kg.ha^{-1} with the same cultivar in Londrina, Paraná state.

In the case of selection Black 145, whose yield was 7,238.92 kg.ha^{-1}, there was no statistical difference among it, Black 112 (5,136.4 kg.ha^{-1}) and 'BRS Xingu' (5,633.9 kg.ha^{-1}). Hussain et al. (2017) had lower yield (1,539.9 kg.ha^{-1}) with Xavante in Paraná state in 2014 than the one found in the experiment.

In the 2017-2018 production cycle, both variables mean number of fruits and yield g.pl $^{-1}$ did not show any significant difference (Table IV). However, in the variable mean fruit mass, there was significant difference among genotypes, since values ranged from 5.0 to7.2 g. Selection Black 112 yielded fruits which weighed 7.3 g (the highest values in this variable), while selection Black 128 yielded fruits with low mass (5.0 g).

Yield in the third production cycle was above 10 ton.ha^{-1}, except selection Black 128, which is considered good blackberry yield. In this cycle, selection Black 145 had the highest yield among genotypes under study, with 14,806.0 kg. ha^{-1}. However, selection Black 128 had the lowest yield (6,766.7 kg.ha^{-1}). The other genotypes yielded 13,684.0 kg.ha^{-1} (selection

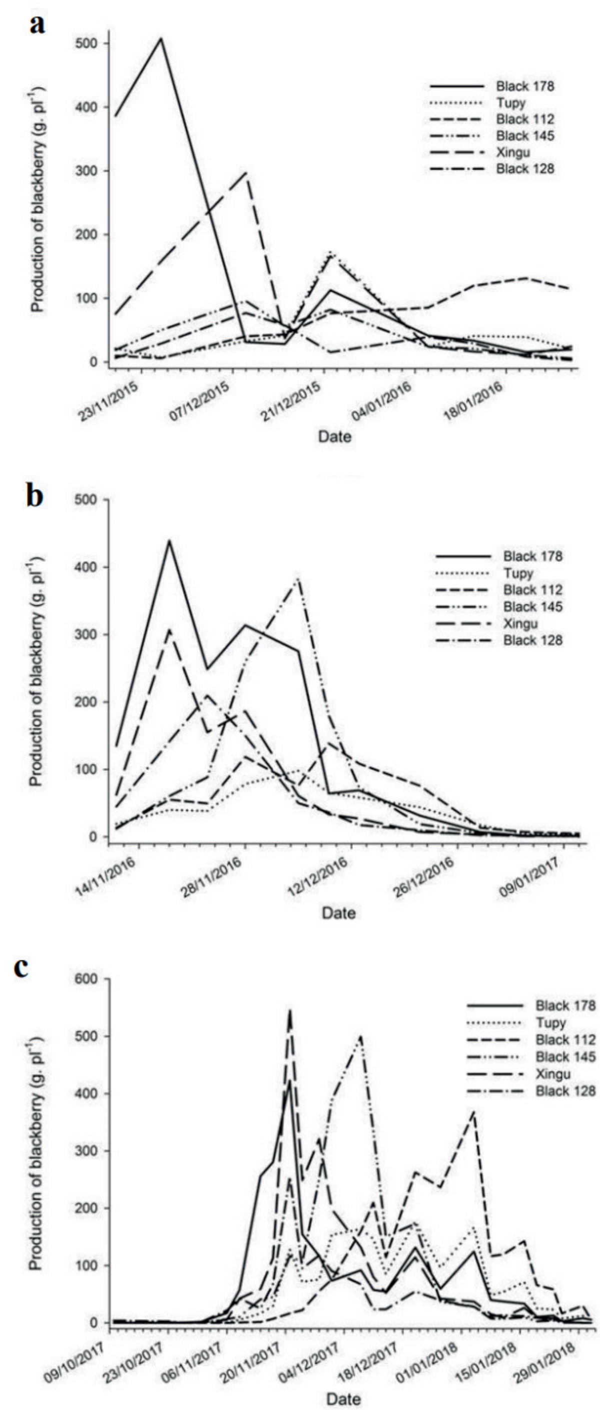

Figure 2. Distribution of blackberry yield in the production cycle 2015-2016 (a); 2016-2017 (b); 2017-2018 (c). Pelotas, RS, Brazil.

Black 178), 13,892.0 $kg.ha^{-1}$ (selection Black 112), 13,741.4 $kg.ha^{-1}$ ('BRS Xingu') and 10,405.3 $kg.ha^{-1}$ ('Tupy').

In the overall yield of genotypes under study in three years, selection Black 178 was found to be the most productive one, since it yielded 32,111.01 $kg.ha^{-1}$. Selection Black 128 had the lowest yield in this period (16,436.70 $kg.ha^{-1}$) (Table V).

In the 2017-2018 crop, harvest started on October 10th (Figure 2c). Selection Black 178 had its production peak (422.77 $g.pl^{-1}$) in the second fortnight in November, along with cultivar BRS Xingu (548.57 $g.pl^{-1}$) and selection Black 128 (254.45 $g.pl^{-1}$).

The production peak of selection Black 145, which was 499.42 $g.pl^{-1}$, occurred later, at the beginning of December. However, selection Black 112 had its peak (367.62 $g.pl^{-1}$) at the beginning of January.

Cultivar Tupy oscillated throughout production, i. e., the highest yield per plant (166.47 $g.pl^{-1}$) occurred in the second fortnight in December.

Production schedule among genotypes was more evident when they were studied together in the same cultivation area. Thus, selections Black 128, Black 178 and Black 145 started to yield firstly, whereas cultivars Black 128, Black 178 and Black 145 started to yield later. It meant a longer harvest period in the region. Besides, oscillation in 'Tupy' yield – observed throughout the crops – may be useful for the fresh fruit market, since fruits can be supplied in different periods. However, similar variation in the production period is not observed in the case of selection Black 145 which has low peaks of fruit supply, a situation that is more appropriate to supply fruits to industries.

Therefore, variation in phenology and yield among blackberry genotypes helps to provide information on their behavior and adaptation to the region by showing promising materials to be grown in organic systems in the region.

CONCLUSIONS

In the agroclimatic conditions found in Pelotas, RS, Brazil, selection Black 178 was the most productive one among genotypes grown in organic production systems. The least productive genotype was selection Black 128.

Selection Black 112 was the latest Genotype in these climate conditions, while selection Black 178 was the most precocious one.

Table V. Overall yield, in $kg.ha^{-1}$, of blackberry genotypes in an organic production system in 2015-16, 2016-17 and 2017-18 crops. Pelotas, RS, Brazil, 2017.

Genotype	2015/2016	2016/2017	2017/2018	Overall yield
Black 178	7844.45	10582.56	13684.00	32111.01
Black 112	2673.34	3114.83	13892.00	19680.17
Black 145	5400.00	5633.90	14806.01	25839.91
Black 128	2431.11	7238.92	6766.67	16436.70
'Xingu'	4177.78	51364.40	13741.34	23055.56
'Tupy'	1768.90	4433.16	10405.34	16607.40

Selections Black 178, Black 112 and Black 145, besides cultivars 'BRS Xingu' and 'Tupy', are genotypes with potential to be grown in organic production systems.

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Author contributions

Rafaela S. Souza planned and developed this study, collected, analysis data and worked writing this paper. Maurício G. Bilharva and Rudinei de Marco worked on crop blackberry and data analysis. Carlos R. Martins and Marcelo B. Malgarim worked on supervision and writing this paper. Luis E.C. Antunes worked writing this paper.