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Research Article

Agronomic performance of strawberry varieties with potential for cultivation on the northern plateau of Santa Catarina state

Desempenho agronômico de cultivares de morangueiro com potencial de cultivo no Planalto Norte Catarinense

Kelly Eduarda Demetrio(ORCID 0000-0002-0322-4494), **Eduardo Virmond Souza Farias**(ORCID 0000-0002-9686-2929), **Otávio Frederico Tschoeke Steidel**(ORCID 0000-0002-8925-9742), **Rodrigo Palinguer**(ORCID 0000-0001-9816-5871), **Caroline de Souza Wisniewski**(ORCID 0000-0002-0322-4494), **Douglas André Würz***(ORCID 0000-0001-6109-9858)

Instituto Federal de Santa Catarina, Canoinhas, SC, Brazil. *Author for correspondence: douglas.wurz@ifsc.edu.br

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ABSTRACT

The evaluation of cultivars to be planted in a region is an important tool for producers to make decisions regarding the replacement of old materials. In this context, the aim is to evaluate the adaptation of new varieties of strawberry for the Planalto Norte of Santa Catarina, to be able to indicate them to producers in the region. The experiment was set up on a rural property in the municipality of Canoinhas, Santa Catarina. The varieties evaluated were Pircinque, Beauty, Sunsation and Brilliance. The design used was randomized blocks, with four repetition and each experimental unit containing 30 plants. The following were evaluated: production (g/plant), yield (t/hectare), fresh fruit mass (g/fruit), fruit diameter and height (mm), % of commercial fruit, % of deformed fruit, % of small fruit, as well as physical and chemical evaluations: soluble solids (°Brix), total acidity (% citric acid), ratio (SS/AT), fruit firmness (kgf). The data was submitted to the variance test (ANOVA) and the means were then submitted to the Tukey test at a 5% probability of error. The Pircinque variety can be recommended for cultivation in the Planalto Norte Catarinense region, by presenting high productive indices, high soluble solid and Ratio, in addition to presenting greater fruit firmness, enabling greater post-harvest conservation. Beauty could also be an alternative for diversifying the varieties grown in the region, as it has good yields and ripens well for strawberry cultivation.

KEYWORDS: *Fragaria x annanasa* Duch. Adaptability of cultivars. Fruit ripeness. Productivity.

RESUMO

A avaliação de cultivares a serem plantadas em uma região é ferramenta importante para que os produtores possam tomar decisões em relação à substituição de materiais antigos. Nesse contexto, o objetivo do trabalho foi avaliar a adaptação de novas cultivares de morangueiro para o Planalto Norte Catarinense a fim de poder indicá-las aos produtores da região. O experimento foi instalado em uma propriedade rural localizada no município de Canoinhas, Santa Catarina. Avaliou-se as variedades: Pircinque, Beauty, Sunsation e Brilliance. O delineamento utilizado foi o de blocos ao acaso, com quatro repetições, e cada unidade experimental contendo 30 plantas. Avaliou-se: produção (g/planta), produtividade (t/ha), massa fresca de frutos (g/fruto), diâmetro e altura de frutos (mm), % de frutos comerciais, % frutos deformados, % frutos pequenos, além de avaliações físico-químicas, sendo: sólidos solúveis (°Brix), acidez total (% ácido citríco), Ratio (SS/AT), firmeza de polpa (kgf). Os dados foram submetidos ao teste de variância (ANOVA) e, quando significativas, submetidas à separação das médias pelo teste de Tukey a 5% de probabilidade de erro. A variedade Pircinque destacou-se entre as testadas por apresentar maior produtividade, elevados teores de sólidos solúveis e Ratio. Em complementou, apresentou maior firmeza de polpa, possibilitando maior conservação pós-colheita. A Beauty pode também ser uma alternativa de diversificação de variedades cultivadas na região, por apresentar bons índices produtivos e maturação adequada para a cultura do morangueiro.

PALAVRAS-CHAVE: *Fragaria x annanasa* Duch. Adaptabilidade de cultivares. Maturação de frutos. Produtividade.

INTRODUCTION

Among the group of small fruits, strawberries (*Fragaria x annanasa* Duch.) are the most representative, accounting for 67% of world production (FAOSTAT 2020). Between the alternative agricultural activities to traditional that ones are being adopted by family farmers looking to diversify and increase income on their properties, with strawberry cultivation standing out (MARCHI et al. 2020). Thise representing a growing and attractive activity within the national market, especially with regard to organic production (BALDIN et al. 2023). In this system, the choice of the cultivar best adapted to the place of cultivation being decisive, considering that interactions between genotypes and the environment can occur (COSTA et al. 2016).

The northern plateau of Santa Catarina has potential for strawberry cultivation, as a way of diversifying production on small farms, with the aim of increasing income (WURZ et al. 2020). However, in a study carried out by WURZ et al. (2019), it was observed that many strawberry producers were unaware of which varieties were grown on their property, and among the cultivars there was a predominance of 'San Andreas' and 'Aromas'. These strawberry cultivars originate from the United States, from breeding programs developed at the Universities of California and Florida (ZANIN et al. 2020). In according to work carried out by WURZ et al. (2021), they are not the ones that demonstrate the greatest productive and qualitative potential in the Planalto Norte Catarinense, so there is a need to evaluate new varieties for this region. Furthermore, according to OLIVEIRA & BONOWE (2012), in Brazilian conditions, these varieties of American origin do not always express their productive potential, in addition to phytosanitary problems.

Evaluating new varieties is an important tool for producers to make decisions about replacing old materials with better adapted cultivars (GUIMARÃES et al. 2015). The availability of few cultivars offered to Brazilian producers means that a series of problems can arise for the producer. As example, the adverse weather conditions that can damage the entire crop synchronized in a single phenological stage and even in the periods of greatest production, causing the producer to have to market all his production for lower prices (FAGHERAZZI 2017).

It should be noted that when introducing new cultivars, it is necessary to carry out adaptability studies, and determine whether these cultivars will express the desired productive potential in different growing locations (COSTA et al. 2015), and thus knowing the different agronomic performances between the genotypes that are available to producers is fundamental for defining strategies for recommending cultivars (COSTA et al. 2019).

A study carried out by WURZ et al. (2021) in the Planalto Norte Catarinense region showed that the Pircinque and Jonica varieties have superior production and quality characteristics compared to other varieties traditionally grown in the region. In this context, the aim of this study is to evaluate four strawberry varieties for the Planalto Norte Catarinense region, looking for cultivars with the best adaptation, which express high levels of fruit production and quality.

MATERIALS AND METHODS

The experiment was set up on a rural property located in the municipality of Canoinhas, Santa Catarina (26°12'49.0“S and 50°26'37.6”O; altitude 870m). The region is characterized by an average annual temperature of between 17 and 18 °C, rainfall of 1,500 to 1,700 mm on average, flat to undulating terrain and medium fertility soils. The region's climate is humid with mild summers, of the Cfb type, average temperatures in the coldest month are below 18 °C and above -3 °C, with cool summers, average temperature in the hottest month below 22 °C, with no defined dry season according to the Köppen classification (WREGE et al. 2012).

The seedlings of the varieties evaluated were planted in May 2022. The cultivars that were planted in the experimental area are of American-Italian origin and are called: Beauty, Brilliance, Pircinque, Sunsation. These are varieties that have already been tested in the state of Santa Catarina and were made available coded so as not to interfere with the evaluations that were carried out.

The design used was randomized blocks, with four repetition and each experimental unit containing 30 plants. Planting took place in slabs, with plants spaced 30 cm apart, totaling density of 60,000 plants per hectare. There was only irrigation in the area, with no fertigation.

Harvesting began in August 2022 and ended in February 2023, at five-day intervals. The fruit was picked in the coolest hours of the day, when at least 75% of the skin was red. At harvest time, the fruit was classified according to the following criteria: (a) commercial - fruit weighing 10g or more and free from rot or deformity; (b) small: fruit weighing less than 10g; (c) deformed - quantified by the percentage of deformed fruit production in relation to total production (% deformed).

At the end of the harvest period, the following production variables were assessed: a) number of fruits per plant, total and commercial (fruits plant^{-1}); b) total yield (g plant^{-1}); c) total yield (ton ha^{-1}) - estimated by multiplying the yield per plant by the planting density used; d) fresh mass of commercial fruits (g fruit^{-1}) - calculated by dividing the commercial yield (g plant^{-1}) by the number of commercial fruits (fruits plant^{-1}) and; e) fruit diameter and length (cm fruit^{-1}), measured using a digital caliper.

Fruit quality was evaluated by six batteries of physicochemical analyses, carried out on September, 2022 and Frebuary, 2023. Analyses were performed at the Laboratory of Physicochemical Analysis of IFSC – Campus of Canoinhas. Laboratory analyzes were: a) fruit firmness - obtained with the aid of a benchtop digital penetrometer, equipped with pressure head with 3.5 mm in diameter, evaluating fifteen fruits per plot, taking two readings on the opposite sides in the equatorial zone of fruits. Values were obtained by the average of all readings performed for each replicate. Results are given in Newtons (N); b) titratable acidity - performed by titrating 5 ml of the juice extracted from all fruits in each plot, using 0.1 N sodium hydroxide (NaOH) solution and phenolphthalein as acid-base indicator at sample color change point. Results were expressed in grams per 100 grams of citric acid (g 100 g^{-1} of citric acid); c) soluble solids content - performed by placing a small sample of juice in the prism of a digital refractometer. Results were expressed in degrees Brix (°Brix); d) soluble solids/titratable acidity ratio (RATIO) - calculated by dividing the results obtained for soluble solids content by the titratable acidity of each sample.

The data was submitted to the variance test (ANOVA) and, when significant, the means were then submitted to the Tukey test at a 5% probability of error.

RESULTS AND DISCUSSION

The production variables of the strawberry varieties evaluated are described in Table 1. The highest yield was observed for the Pircinque variety, with an average of 503.2 g/plant, followed by Beauty, with an average value of 333.1 g/plant, while the Sunsation and Brilliance varieties had average yields of 225.7 and 233.5 g/plant, respectively.

Table 1. Production variables in strawberries of the Pircinque, Beauty, Sunsation and Brilliance varieties, produced in the Planalto Norte Catarinense. Canoinhas/Santa Catarina, harvest 2022/2023.

Variety	Production g plant^{-1}	Productivity ton ha^{-1}	Fresh weight g fruit^{-1}
Pircinque	503,2 a	55,9 a	23,5 ns
Beauty	333,1 b	37,1 b	23,4
Sunsation	225,7 c	25,2 c	24,3
Brilliance	233,5 c	25,9 c	23,7

Based on the data obtained for production per plant, the highest yield was 55.9 t/hectare for the Pircinque strawberry, followed by Beauty with 37.1 t/hectare. The lowest yields were observed for the Sunsation and Brilliance varieties, with 25.2 and 25.9 tons/hectare, respectively. It is very important to evaluate yield indices, as according to RONQUE et al. (2013), high yield indices are essential to make the activity viable, especially on small properties. Productive data from the Pircinque variety in this study is higher than that observed by ZANIN et al. (2020), in the Planalto Sul Catarinense region, and similarly to observed by WURZ et al (2021), in the Planalto Nort Catarinense region.

Fruit number and weight are the main components of strawberry production (OLIVEIRA & BONOW 2012). However, the fresh mass variable (grams/fruit) showed no statistically significant differences, with values of 23.5, 23.4, 24.3 and 23.7 grams/fruit observed for the Pircinque, Beauty, Sunsation and Brilliance varieties, respectively. Therefore, the difference in productivity is directly related to the number of fruits produced per plant.

ROSA et al. (2020), points out that in the marketing of fresh strawberry fruits, parameters related to size and mass are fundamental.

The fruit harvested was classified according variables described in Table 2. There were no significant differences for the variables fruit diameter, % commercial fruit, % deformed fruit and % small fruit, with a predominance of commercial fruit and fruit with diameters ranging from 32.3 to 34.6 mm. Regarding the fruit height variable, there were differences between the varieties evaluated. Fruits harvested from the Pircinque and Sunsation varieties had the highest fruit height values, with 52.8 and 52.7 mm, respectively, while the Beauty and Brilliance varieties had fruit heights of 45.5 mm.

Table 2. Classification in terms of visual and/or measurable issues of diameter, height, commercial potential, deformity, and size of the strawberry fruit evaluated. Canoinhas/Santa Catarina, harvest 2022/2023.

Variety	Sorting the harvested fruit				
	Diameter Fruit	Height Fruit	Commercial	Deformed	Small
	mm	mm	%	%	%
Pircinque	32,3 ns	52,8 a	85,6 ns	1,8 ns	1,6 ns
Beauty	34,1	45,5 b	84,6	1,9	2,0
Sunsation	32,3	52,7 a	84,9	2,2	1,9
Brilliance	34,6	45,5 b	87,6	2,1	2,1

In comparison with other studies, this study showed similar data for % marketable fruit to WURZ et al. (2021) in the Planalto Norte Catarinense region, and higher data than that observed by ZANIN et al. (2020), in the Planalto Sul Catarinense region, indicating qualitative fruit production. Also, according to ZANIN et al. (2020), the percentage of marketable fruit is one of the main production parameters, as it directly affects the economic viability of the investment.

The data related to the physicochemical evaluations are described in Table 3. The analyzed variables were influenced by the varieties to soluble solids, total acidity, ratio (SS/AT) and flesh firmness. The highest value for soluble solids was observed in the Pircinque variety, with 10.1 ºBrix, followed by Beauty with 7.9 ºBrix, while the Sunsation and Brilliance varieties had the lowest values for this variable, with 6.3 and 6.2 ºBrix, respectively.

Table 3. Soluble solids (SS), total acidity (AT), RATIO (ratio between soluble solids and total acidity), fruit firmness (FIR). Canoinhas/Santa Catarina, harvest 2022/2023.

Variety	Qualitative variables			
	Soluble Solids	Total acidity	RATIO	Fruit firmness
	°Brix	% Citric acid	SS/AT	kgf
Pircinque	10,1 a	0,51 b	19,6 a	1,21 a
Beauty	7,9 b	0,62 a	12,7 b	0,87 b
Sunsation	6,3 c	0,67 a	9,4 c	0,86 b
Brilliance	6,2 c	0,68 a	9,1 c	0,88 b

Regarding the total acidity variable, the lowest value was observed for Pircinque, with 0.51 % citric acid, while the Beauty, Sunsation and Brilliance varieties showed similar values for this variable, with 0.62, 0.67 and 0.68 % citric acid, respectively. Low total acidity values are sought for fresh fruit, as high levels can compromise consumer acceptance of the fruit (RESENDE et al. 2008).

Based on the values observed for soluble solids and total acidity, the Ratio (SS/AT ratio) was calculated, in which the highest values were observed for Pircinque, with 19.6, followed by the Beauty variety (12.7), while the Sunsation (9.4) and Brilliance (9.1) varieties showed similar Ratio. The high soluble solids/titratable acidity ratio in the Pircinque variety has already been reported by several authors (FAGHERAZZI 2017, ZANIN et al. 2020, WURZ et al. 2021), thus indicating that it is a characteristic of this variety. In a commercial variety, it is essential that there is an adequate balance between acidity and soluble solids content (CARPENEDO et al. 2016), with the soluble

solids/titratable acidity ratio being one of the most important qualitative variables (ZANIN et al. 2020).

Fruit firmness was influenced by the varieties evaluated. The highest value observed for the Pircinque variety, at 1.21 kgf. The Beauty, Sunsation and Brilliance varieties showed values that did not differ from each other, which were 0.87, 0.86 and 0.88 kgf, respectively. Fruit firmness are more resistant to damage during transportation and have greater post-harvest durability and resistance to rot (OLIVEIRA & BONOW 2012). According to ZANIN et al. (2020), this is one of the most important characteristics in strawberry genetic improvement.

The high fruit firmness turn is possible to store for a longer period and market it to more distant locations (BRACKMANN et al. 2011). A study carried out by WURZ et al. (2021) in the Planalto Norte region of Santa Catarina found high fruit firmness for Pircinque compared to six other strawberry genotypes.

Strawberry varieties must have the following parameters for fresh fruit marketing: a minimum of 7.0 °Brix for soluble solids content; a maximum of 0.8% citric acid for titratable acidity; and a minimum of 8.75 for soluble solids/titratable acidity ratio (SOUZA et al. 2017). Following these parameters, Pircinque and Beauty had all the ideal parameters, while the Sunsation and Brilliance varieties had lower parameters for soluble solids, but adequate ones for total acidity and SS/AT ratio.

CONCLUSION

This study can be concluded that the Pircinque variety can be recommended for cultivation in the Planalto Norte Catarinense of Santa Catarina State. This variety has high yields, high soluble solids and Ratio levels, as well as higher fruit firmness, allowing for better post-harvest preservation.

The Beauty variety could also be an alternative for diversifying the varieties grown in the region, as it has good yields and ripens well for strawberry cultivation.

AUTHOR CONTRIBUTIONS

Conceptualization, methodology, and formal analysis**, Douglas André Wurz,** ; software and validation**, Douglas André Wurz;** investigation**, Caroline de Souza Wisniewski, Kelly Eduarda Demetrio, Rodrigo Palinguer, Eduardo Virmond Souza Farias and Otávio Steidel**; resources and data curation **Caroline de Souza Wisniewski, Kelly Eduarda Demetrio, Rodrigo Palinguer, Eduardo Virmond Souza Farias and Otávio Steidel**; writing-original draft preparation**, Caroline de Souza Wisniewski, Kelly Eduarda Demetrio, Rodrigo Palinguer, Eduardo Virmond Souza Farias and Otávio Steidel**; writing-review and editing**, Caroline de Souza Wisniewski, Kelly Eduarda Demetrio, Rodrigo Palinguer, Eduardo Virmond Souza Farias and Otávio Steidel**; visualization**, Caroline de Souza Wisniewski, Kelly Eduarda Demetrio, Rodrigo Palinguer, Eduardo Virmond Souza Farias and Otávio Steidel**; supervision, **Douglas André Wurz**; project administration, **Douglas André Wurz**;. All authors have read and agreed to the published version of the manuscript.

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INFORMED CONSENT STATEMENT
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DATA AVAILABILITY STATEMENT
The data can be made available under request.

CONFLICTS OF INTEREST
The authors declare no conflict of interest.

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