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Quality of strawberries of Italian origin grown in the mountainous region of Rio Grande do Sul

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ABSTRACT: Studies that evaluate the quality of the strawberry fruit, depending on the different genetic materials and places of cultivation, are still scarce in Brazil. The objective of this work was to evaluate the quality of fruits of advanced genotypes of strawberry with Italian genetics, in the municipality of Farroupilha, belonging to the Serrana region of Rio Grande do Sul. The experimental design was in randomized blocks, with four replications and 10 plants per plot, in two production cycles, containing 21 treatments in the 2018/2019 cycle and 23 treatments in the 2019/2020 cycle. The variables were quantified: fresh mass of commercial fruits (g fruit^{-1}); luminosity and chroma of the epidermis; hue angle; pulp firmness (g); titratable acidity content (g 100g^{-1} of citric acid); soluble solids content (°Brix) and soluble solids/titratable acidity ratio (SS/AT). Among the genotypes evaluated, the genotypes FRF PIR 075.08, ITA 10.128.09, and FRF FC 104.01, have superior fruit quality, showing greater potential to become recommended cultivars for cultivation in the Serrana region of Rio Grande do Sul, together with the cultivar Pircinque.

Key words: climate; *Fragaria* x *ananassa* Duch.; *in natura* market; genotypes

Qualidade de morangos de origem italiana cultivados na região serrana do Rio Grande do Sul

RESUMO: Estudos que avaliem a qualidade do fruto do morangueiro, em função dos diferentes materiais genéticos e lugares de cultivo, ainda são escassos no Brasil. Objetivou-se com este trabalho avaliar a qualidade de frutos de genótipos avançados de morangueiro com base genética italiana, no munícipio de Farroupilha, pertencente a região Serrana do Rio Grande do Sul. O delineamento experimental foi em blocos casualizados, com quatro repetições e 10 plantas por parcela, em dois ciclos produtivos, contendo 28 tratamentos no ciclo 2018/2019 e 39 tratamentos no ciclo 2019/2020. Foram quantificadas as variáveis: massa fresca de frutos comerciais (g fruto^{-1}); luminosidade e croma da epiderme; ângulo hue; firmeza de polpa (g); teor de acidez titulável (g 100g^{-1} de ácido cítrico); teor de sólidos solúveis (°Brix) e relação sólidos solúveis/ acidez titulável (SS/AT). Dentre os genótipos avaliados, os genótipos FRF PIR 075.08, ITA 10.128.09 e FRF FC 104.01, apresentam qualidade superior de fruto, demonstrando maior potencial para se tornarem cultivares recomendadas para o cultivo na região Serrana do Rio Grande do Sul, juntamente com a já cultivar Pircinque.

Palavras-chave: clima; *Fragaria* x *ananassa* Duch.; mercado *in natura*; genótipos

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Introduction

The national strawberry producing poles depend almost exclusively on varieties obtained from breeding programs outside Brazil. However, the introduction of new cultivars in the country should be preceded by studies to evaluate the adaptability of these plants in Brazilian regions, exposed to the different existing climatic conditions, including those that are also adverse to the environmental conditions in which they were selected (Galvão et al., 2017). Therefore, it is of great importance to conduct studies with new genetic sources, encouraging the national breeding programs to introduce and create materials adapted to the producing regions, expanding the genetic resources available for commercial cultivation (Cocco et al., 2020).

The diversity of materials with distinct fruit characteristics, necessitate studies of adaptation to different growing systems and different locations (Zanin, 2019). Environmental factors have a major influence on the growth, development, and quality of the fruit. Temperature is one of the main factors that affect the production and quality of strawberries, and is considered the main limiting factor of the crop. The influence of temperature on the fruit, besides being physical (shape, color, firmness), also directly affects their flavor and aroma. Rainfall, solar radiation, and air humidity are environmental factors that can also affect the quality of strawberry fruit (Gonçalves et al., 2016).

Strawberry quality is directly related to volatile compounds, soluble sugars, amino acids, and organic acids that impart flavor to the fruit (Taiz et al., 2017; Farnezi et al., 2020). Although there are several studies on the quality and nutritional content of strawberry, there is still a gap in studies evaluating the quality of strawberry fruit as a function of different genetic materials and growing locations with distinct environmental conditions (Zanin, 2019).

The production of the plant is of great importance for strawberry growers, but more than this is the quality of the fruit, since their commercialization depends directly on the acceptance of the consumer market, which is based largely on the appearance of the fruit. In addition, the consumption habit is due to the fruit flavor, constituted basically from sugars and organic acids contained in the fruit (Farnezi et al., 2020).

With this, it is important to emphasize that the proper choice of a cultivar is not only supported by the productive aspects, but also by materials that produce quality fruit and meet the demands of the consumer market. The Italian genetic material, besides its productive characteristics, is selected for the quality of its fruits. The study of these materials, cultivated in different locations, will enable the indication of new cultivars, with options of quality fruits, with firmness, color, and differentiated flavor, increasing the supply of fruit in the south Brazilian region. Due to this, the present study aimed to evaluate the fruit quality of advanced strawberry genotypes with Italian genetic basis in the municipality of Farroupilha, located in the mountainous region of the state of Rio Grande do Sul, Brazil.

Materials and Methods

The trials were conducted in the strawberry seedling production nursery PASA, in an agricultural area located at 29° 12’ 16” S latitude and 51° 19’ 03” W longitude, at an altitude of 720 m, in the municipality of Farroupilha, state of Rio Grande do Sul, Brazil. The climate is classified as humid subtropical mesothermal Cfb, according to Köppen. The annual rainfall is approximately 1,837 mm and the average annual temperature is 16.2 °C, the experiment being carried out in their harvests. More details about the maximum and minimum average temperature data and monthly rainfall during the conduction of the trials in the municipality of Farroupilha, can be seen in the Table 1.

In the 2018/2019 cycle, the experiment was conducted with 21 treatments, composed of American cultivars, Spanish cultivar, genotypes of Italian origin from the Consiglio per la ricerca in agricoltura e l’analisi dell’economia agraria Centro di Olivicoltura, Frutticoltura e Agrumicoltura (CREA-OFA) and Italian-based genotypes selected in Brazil by the Universidade do Estado de Santa Catarina. The seedlings used in the trial were produced in a commercial nursery located in Farroupilha, RS, Brazil, from stolons collected in the field and rooted in 72-cell trays.

The 21 treatments were composed of the short day genotypes: Jonica, Pircinque, Sabrina, FRF LAM 269.18, FRF PIR 075.08, FRF PIR 256.04, FRF PA 109.02, FRF PIR 079.06, ITA 10.133.02, ITA 10.133.07, ITA 13.079.01, ITA 13.079.02, ITA 13.097.05, ITA 10.107.12, ITA 10.107.07, ITA 10.107.06, ITA 12.103.06, ITA 12.103.12, ITA 12.103.15, ITA 12.103.22, and ITA 10.128.09.

The experiment was installed in a system of growing beds, suspended one meter from the ground, 20 cm wide and 20 cm deep, which were filled with substrate, composed of 60% carbonized rice husk and 40% peat, and covered with 25 cm thick white and black double-sided mulching. The covering of the beds was individual, every two planting rows, in the format of low tunnels, covered with transparent polyethylene plastic. The seedlings were transplanted in June, using randomized block design, with four repetitions, each experimental unit consisting of 10 plants, with spacing of 0.15 m between plants and 0.30 m between rows, in a double row.

The cultivation system and plant management was entirely carried out by the producer. The irrigation system used was via 10 cm drippers and fertilization was done via fertigation with formulation according to chart 3, recommended commercially (Yara®) for strawberry crops, using salt compounds already formulated in order to maintain the pH always in the range of 5.5 to 6.5 and electrical conductivity of the drainage of 1.2 to 1.5 mS cm^{-1}. The cleaning of the plants was done manually, as needed, removing diseased and senescent leaves. Weed control, as well as phytosanitary control was carried out as needed, with the use of products recommended and registered for the crop by the Ministério da Agricultura in Agrofit.

In the 2019/2020 cycle, the experiment consisted of 23 treatments, consisting of the short day genotypes: Jonica, Pircinque, Camino Real, Oso Grande, Merced, Fronteras, Sabrina, FRF PIR 256.04, FRF PIR 075.08, FRF LAM 269.18,

Table 1. Average maximum and minimum temperature and monthly rainfall during the conduction of the trials in the municipality of Farroupilha, RS, Brazil, 2020.

2018/2019 harvest										
	May/18	**Jun/18**	**Jul/18**	**Aug/18**	**Sept/18**	**Oct/18**	**Nov/18**	**Dec/18**	**Jan/19**	**Feb/19**
Average - maximum temp. (°C)	16.0	12.3	13.6	12.5	17.5	17.7	20.7	21.8	24.1	21.7
Average - minimum temp. (°C)	15.1	11.4	12.7	11.5	16.5	16.7	19.6	20.6	23.0	20.6
Rainfall (mm)	118.6	193.2	163.0	215.8	183.0	221	191.0	134.4	138.0	66.2
Average - maximum RH (%)	82.9	86.0	85.1	81.2	82.0	80.8	74.4	75.6	93.5	79.5
Average - minimum RH (%)	79.1	81.9	81.5	76.7	77.4	76.0	68.7	69.4	88.1	74.4
2019/2020 harvest										
	May/19	**Jun/19**	**Jul/19**	**Aug/19**	**Sept/19**	**Oct/19**	**Nov/19**	**Dec/19**	**Jan/20**	**Feb/20**
Average - maximum temp. (°C)	15.2	16.7	12.7	14.0	15.9	19.0	20.4	23.1	22.8	22.2
Average - minimum temp. (°C)	14.6	15.8	11.8	12.9	14.8	18.0	19.3	21.7	21.8	20.9
Rainfall (mm)	70.4	69.2	44.0	97.2	72.8	258.6	158.6	37.4	144.6	67.4
Average - maximum RH (%)	91.9	80.1	80.5	76.6	77.8	79.7	77.8	64.9	75.5	73.3
Average - minimum RH (%)	89.5	76.0	87.5	76.3	72.8	75.0	72.7	58.6	69.9	67.6

Source: INMET (2020). Station A840 - Bento Gonçalves. Latitude: -29,16481. Longitude: -51,534202. Altitude: 623 m.

FRF PA 109.02, FRF PIR 079.06, ITA 10.133.02, ITA 13.079.02, ITA 13.097.05, ITA 12.190.02, ITA 10.107.12, ITA 10.107.07, ITA 10.107.06, ITA 12.103.06, ITA 12.103.12, ITA 12.103.22, and ITA 10.128.09. The trial used rootstock seedlings produced in a commercial nursery located in Farroupilha, RS, Brazil, from stolons collected in the field and rooted in 72-cell trays. With the exception of the cultivars Oso Grande, Camino Real, Merced, and Fronteras, for which cold storage seedlings made available by Bioagro® were used.

The experiment was conducted in the same system as last season, in suspended growing beds with substrate, but with plastic covering in the form of an umbrella. The seedlings were transplanted in June, in a randomized block design, with four repetitions and each experimental unit formed by 10 plants, using spacing of 0.15 m between plants and 0.30 m between rows.

The substrate was composed of 40% peat and 60% carbonized rice husk. Fertigation was localized, using 10 cm drippers, according to the commercial formulation specified in chart 7, incorporated in the irrigation water, keeping the electrical conductivity of the drainage from 1.2 to 1.5 mS cm^{-1} and pH in the range of 5.5 to 6.5. The weed control was done with a manual brush cutter and the phytosanitary treatments were done according to the recommendations for the crop. The cleaning of the plants was done manually, as needed.

In both harvests, the experiment was accompanied and visually evaluated in a field report. In each of the flowerings, the fruits were collected with a predominance of 75% of the red epidermis, and a sample of 10 uniform fruits was collected per plot. Afterwards, these fruits were packed and taken to Lages, SC, Brazil, at Universidade do Estado de Santa Catarina biotechnology laboratory, in styrofoam refrigerated boxes with ice. The samples were weighed on a semi-analytical balance and the estimated average mass per fruit was calculated.

The physical-chemical analyses were performed in samples of 10 fruits per repetition, for which the coloration of the fruit epidermis was analyzed with the aid of a Minolta digital colorimeter, through which the parameters of luminosity (L*), chroma (C*), and °hue (color angle) were evaluated; and pulp firmness, expressed in grams of force necessary to break the fruit epidermis, using a Texture Analyser TA.XT.plus texturometer (Stable Micro Systems Ltd, Vienna Court, UK). We also analyzed the soluble solids content, expressed by the concentration of sugars present in the fruits (°Brix) and quantified with the aid of a digital refractometer; the titratable acidity content, expressed by the content of citric acid present in the fruits, determined by means of an automatic titrator TITRONIC®, diluting 5 mL of juice in 45 mL of distilled water, followed by titration with a NaOH 0.1 M solution until pH 8.1, the SS/TA ratio, calculated by the ratio between the content of soluble solids and titratable acidity and the estimated average mass of commercial fruits by dividing the weight of the sample by the total number of fruits.

The data were analyzed separately for each of the harvests. Within each situation, the Shapiro-Wilk normality test was performed using R software (R Core Team, 2013) via the Action Stat interface. However, for some variables, it was necessary to perform the transformations described below:

For the 2018/2019 harvest, titratable acidity data for the short day genotypes and flesh firmness and average commercial fruit mass data for the neutral day genotypes were transformed by the formula $Y= \sqrt{(x + 0.5)}$.

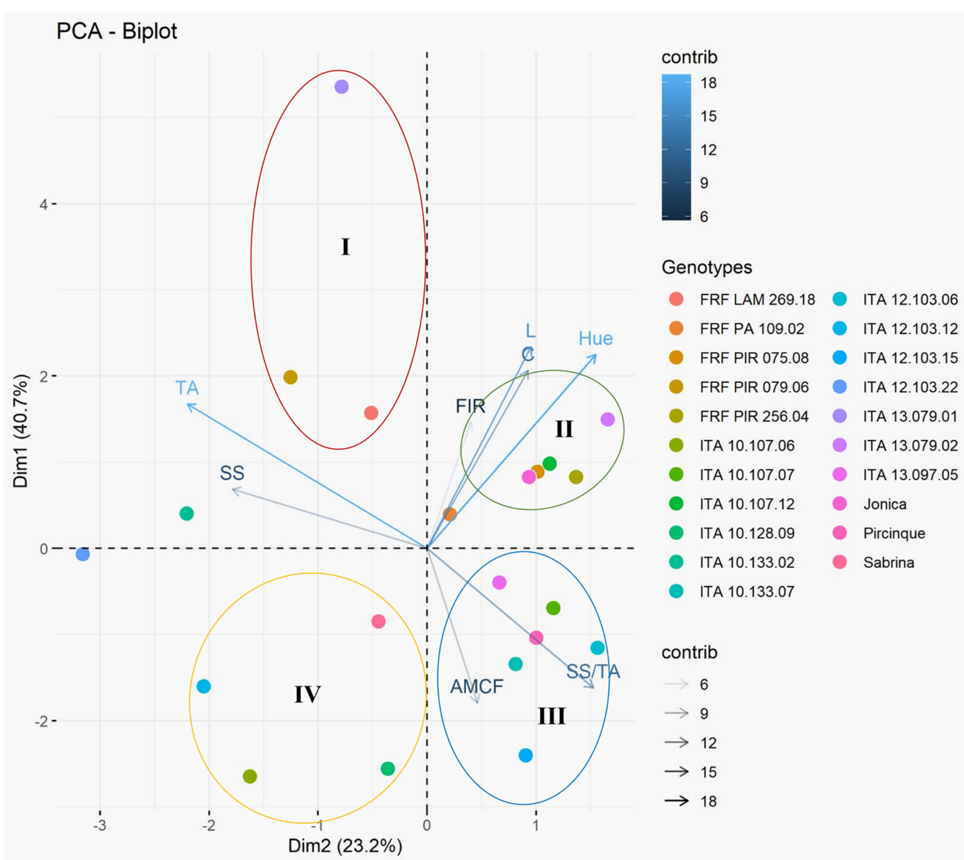
When normality conditions were met, the data were subjected to univariate and multivariate analysis. For the multivariate analysis we performed a Principal Component Analysis (PCA), which was used as the basis for interpretation and further discussion of the data, because it allows a better understanding of the distribution and composition of the treatments, as well as their interaction with the variables analyzed. The univariate analysis of variance and the comparison of means compared by the Scott Knott test at 5% error probability, were also performed, however, as a means to prove significant differences throughout the interpretations performed from the PCA. For univariate analysis the statistical software SISVAR (Ferreira, 2011) and for PCA the software Fitopac 2.1 (Shepherd, 2010) was used.

Results and Discussion

For the 2018/2019 harvest, the PCA for the short day genotypes resulted in the identification of mainly three groups (Figure 1).

Group I was composed of the genotypes FRF LAM 269.18, ITA 13.079.01, and FRF PIR 079.06, which showed a positive correlation with the SS variable, the latter showing the highest value among them (Table 2). However, it was not enough to reach high values of SS/TA ratio, due to its high positive correlation, also with the titratable acidity vector, for which it reached levels close to the maximum limit of 0.8 g $100g^{-1}$ of citric acid, for strawberry fruits, considered by Chitarra & Chitarra (2005). It is also worth noting that in addition to the influences cited above, the genotype ITA 13.079.01, in particular, correlated strongly with the coloration attributes, a factor that most strongly influenced its disposition in the PCA. This is due to the high luminosity and chroma values of the epidermis seen in the fruits of this genotype, resulting in a high hue angle as well, tending toward a lighter red coloration, but with high brightness and color purity (Castricini et al., 2017).

The positive correlation that occurred between the genotypes ITA 13.079.01 and PIR 079.06 and the SS variable vector, is due to the fact that these genotypes produced fruits with higher concentration of soluble sugars, on average, 22.9% higher than the overall average obtained (Table 2). It was found that these genotypes, in the present harvest exceeded the sugar concentration of the cultivars under study (Pircinque, Jonica, and Sabrina), selected and known for the sweetness of their fruits (Faedi et al., 2014; Morello, 2014;



L - epidermis luminosity; C - epidermis chroma; Hue - epidermis Hue angle; SS - soluble solids; TA - titratable acidity; SS/TA - soluble solids/titratable acidity ratio; FIR - pulp firmness; AMCF - average mass of commercial fruits.

Figure 1. Principal component analysis for the short day genotypes and parameters studied in the fruit quality trial, in the 2018/2019 harvest in the municipality of Farroupilha, RS, Brazil. Lages, SC, Brazil, Udesc, 2021.

Table 2. Average mass of commercial fruits (AMCF) (g fruit^{-1}), fruit pulp firmness (FIR) (g fruit^{-1}), epidermis luminosity (L*), epidermis chroma (C*), hue angle (°Hue), soluble solids (SS) (°Brix), titratable acidity (TA) (g 100g^{-1} of citric acid), and soluble solids/titratable acidity ratio (SS/TA), of short and neutral day strawberry cultivars and advanced genotypes. Lages, SC, Brazil, Udesc, 2020.

2018/2019 harvest								
Genotype	AMCF	FIR	L*	C*	°Hue	SS	TA	SS/TA
Short day								
Jonica	20.76 c	140.50 c*	35.90 c*	44.08 d	31.03 e	6.3 c	0.55 b	11.32 c
Pircinque	29.72 a	141.57 c	34.98 c	42.29 e	30.05 e	6.9 b	0.52 b	13.17 b
Sabrina	25.74 b	148.37 c	31.77 f	42.49 e	27.84 c	6.6 c	0.61 c	10.75 c
FRF LAM 269.18	24.50 b	219.90 a	35.03 c	42.62 e	29.53 e	6.2 c	0.74 d	8.25 d
FRF PIR 075.08	27.98 a	160.07 b	36.89 b	44.55 d	30.39 e	5.4 d	0.63 c	8.60 d
FRF PIR 256.04	20.65 c	137.00 c	34.28 d	46.44 b	32.12 f	6.4 c	0.52 b	12.17 b
FRF PA 109.02	23.93 b	122.62 d	37.04 b	43.69 d	28.53 d	6.5 c	0.61 c	10.72 c
FRF PIR 079.06	19.86 c	152.55 b	36.70 b	44.31 d	29.81 e	8.0 a	0.74 d	10.75 c
ITA 10.133.02	24.18 b	163.65 b	33.03 e	41.57 f	27.32 c	7.4 b	0.80 d	9.22 d
ITA 10.133.07	25.95 b	161.37 b	34.32 d	42.53 e	26.77 c	7.2 b	0.48 a	14.97 a
ITA 13.079.01	19.12 c	137.92 c	40.93 a	51.64 a	34.59 g	8.2 a	0.90 e	9.05 d
ITA 13.079.02	20.79 c	167.70 b	36.57 b	45.28 c	33.07 f	6.6 c	0.52 b	12.45 b
ITA 13.097.05	21.77 c	136.75 c	35.80 c	41.63 f	28.47 d	6.6 c	0.51 b	12.77 b
ITA 10.107.12	18.83 c	164.87 b	36.34 b	41.60 f	32.04 f	6.2 c	0.53 b	11.67 c
ITA 10.107.07	28.30 a	101.45 d	35.53 c	46.29 b	28.56 d	6.5 c	0.52 b	12.42 b
ITA 10.107.06	26.29 b	106.47 d	30.42 g	39.53 h	24.32 b	7.2 b	0.61 c	11.90 c
ITA 12.103.06	24.67 b	144.07 c	32.93 e	43.91 d	28.68 d	5.9 d	0.45 a	13.10 b
ITA 12.103.12	22.59 c	109.87 d	31.77 f	41.66 f	22.44 a	7.2 b	0.65 c	10.92 c
ITA 12.103.15	27.50 a	91.50 d	32.07 f	43.22 d	26.84 c	5.9 d	0.47 a	12.67 b
ITA 12.103.22	21.31 c	115.75 d	32.39 f	40.98 g	25.06 b	7.2 b	0.85 e	8.45 d
ITA 10.128.09	26.21 b	97.40 d	33.61 e	41.12 g	23.87 b	7.3 b	0.51 b	14.22 a
Overall average	23.84	139.11	34.66	43.40	28.63	6.7	0.61	11.40
CV (%)	11.10	8.54	2.19	1.71	2.74	6.04	2.02**	8.87

* Means followed by the same letter in the column do not differ by the Scott-Knott test ($p \geq 0.05$).
** Data transformed by the formula $Y= \sqrt{(x + 0.5)}$.

Ahmadi et al., 2017; Fagherazzi et al., 2017). Fruit sweetness is a fundamental characteristic in the marketing of the fruit, because it is attributed by the consumer as a positive characteristic to strawberry flavor, thus being a parameter of great relevance in the launch of new cultivars (Richter, 2018).

Sugar content in fruit, besides being a genetic trait can be largely influenced by plant management and climatic conditions (Costa et al., 2019). These lower SS values obtained in the present study, may be related to the number of cloudy and rainy days that occurred mainly during the months of September, October, and November in the 2018/2019 harvest and to an excess of irrigation and nitrogen fertilization, performed by the producer, which resulted in good sized fruits. However, these became more “watery”, with less flavor and consequently less pulp firmness, as shown earlier. Lower sun exposure, brings damage to net photosynthesis of plants, consequently decreasing the accumulation of sugars and directly reflecting in lower sweetness in the fruit (Taiz et al., 2017).

The genotype FRF LAM 269.18, on the other hand, despite also belonging to group I, showed less influence of the SS and coloration vector, unlike the other genotypes belonging to this group. However, it correlated positively with the TA vector, as did the others, but with greater influence from the pulp firmness vector. It also produced large fruits, with considerable fresh mass, also influenced by the AMCF vector. The genotype FRF LAM 269.18, showed the highest pulp firmness among the genotypes, with its fruits being 58.1% firmer than the general average obtained. Cocco et al. (2017), studying the agronomic performance of different Italian genotypes, also in the municipality of Farroupilha, SC, Brazil, found a high firmness value for the genotype FRF LAM 269.18, of 544.0 g of strength, an average higher than the one found in this study. In a study conducted by Zanin et al. (2019), in the municipality of Lages, SC, Brazil, a high value of firmness was also verified for this genotype, of 5.67 N, corresponding to 578.18 g of strength, however, without differing from the other genotypes tested by them. Still, the value was higher than that found in the present study (Table 2). The maintenance of fruit firmness is an important quality parameter, since it is directly related to texture aspects and postharvest conservation (Chitarra & Chitarra, 2005).

Different factors can influence the firmness of strawberry fruit, from genetic and management characteristics, factors that can be controlled, to environmental factors (Zanin, 2019), which is beyond the grower control, or the method of analysis used. A possible explanation for the difference in pulp firmness of the genotype FRF LAM 269.18 compared to the cited studies, may be the environment and climatic conditions in the different agricultural cycles. An example of this is the study conducted by Cocco et al. (2017), also in the municipality of Farroupilha, who evaluated the fruit only in the month of November, when there is still no occurrence of very high temperatures on most days. In the present study four analyses were performed, one in December and another at the end of the cycle in January, when temperatures are already higher (Table 1), using the average of these four analyses to arrive at the final value, which may have resulted in a lower final firmness of these fruits. High temperatures shorten the interval between flower fertilization and fruit maturation, resulting in a lower rate of cell division. With that, when the fruit grows in size, it increases the cell content, which can dilute the calcium content inside the cells, decreasing the strength of the cell wall and consequently the fruit epidermis (Taiz et al., 2017).

It is also worth noting the strong influence of acidity on the fruit flavor of these genotypes, briefly highlighted earlier, which resulted in a reduction in the average value of the SS/TA ratio not only for the genotypes LAM 269.18, ITA 13.079.01, and PIR 079.06, but all the genotypes studied, since the contents of soluble solids were not very high in this harvest. Titratable acidity represents the concentration of organic acids present in the fruit, which when in balance (SS/TA ratio), represents an important quality attribute, since many of these, being volatile also confer aroma to the fruit (Farnezi et al., 2020).

In group II remained allocated the genotypes ITA 13.079.02, ITA 10.107.12, FRF PIR 256.04, FRF PIR 075.08, and Jonica, which correlated mainly with the qualitative variables of coloration (brightness, chroma, and hue angle). This clear separation from the other genotypes, in this harvest, is due to the fruits of these genotypes having presented a lighter, orange color, which is not a very desirable characteristic in the consumer market, since they correlate the coloration to the flavor of the fruit (Zanin, 2019). This was not confirmed for the genotype ITA 13.079.01 that despite having the highest soluble solids content among the short day old genotypes tested, was also strongly and positively correlated with the color attributes, with the fruits being more orange, as previously mentioned, despite producing fruits with higher sugar content, showing the need for further studies to prove its characteristics in different locations and environmental conditions.

The genotypes ITA 12.103.12, ITA 10.107.06, and ITA 10.128.09 and the cultivar Sabrina composed the group number IV, which were responsible for the production of fruits with more intense red coloration, which explains the opposite disposition of these genotypes to the color vectors, showing a negative correlation with them. The more intense red tone in the epidermis of the fruits is related to the content of anthocyanins, which the higher their concentration, the lower the hue angle of the fruits tends to be, that is, the red coloration becomes more intense, and the content of anthocyanins in the fruits varies according to the genotype. Anthocyanins are directly linked to the nutraceutical quality of strawberries, as they are functional compounds, responsible for the antioxidant property contained in the fruit and adding value to strawberry consumption (Kovačević et al., 2015). However, it is worth noting that in addition to the correlation described above, they suffered influence from other vectors, as is the case of the genotypes ITA 10.107.06, ITA 10.128.09, and the cultivar Sabrina that correlated positively, also with the AMCF vector and the genotype ITA 12.103.12 that suffered influence from the SS vector.

Group III was formed by the genotypes ITA 12.103.06, ITA 12.103.15, ITA 10.133.07, ITA 10.107.07, ITA 13.097.05, and the cultivar Pircinque, this group being more closely related to the average mass of commercial fruits, due to most of them producing fruits with larger size. The average fruit mass variable is very important in strawberry marketing, since it is directly related to the size of the fruit (Farnezi et al., 2020), so the higher the average mass, the greater the tendency of that fruit to have a high size as well.

However, the largest fruits, with the highest average mass achieved, were observed in the cultivar Pircinque, but with an average mass very similar to the fruits of the genotypes ITA 10.107.07, FRF PIR 075.08, and ITA 12.103.15. This high average fruit mass of the Pircinque cultivar corroborates with that found by Fagherazzi et al. (2012), who verified a value very close to that found in this study, of 30.6 g fruit^{-1}. The genotype ITA 10.107.07 that showed the second highest average mass, was selected in Brazil, coming from a cross, in which one of its genitors is the cultivar Pircinque (Zanin, 2019), which explains this good performance in fruit size and quality, visibly inherited from it. The cultivar Pircinque was selected for southern Italy due to the good adaptability demonstrated in that region, a result of its low cold requirement (Fagherazzi et al., 2012), which allowed the good adaptability of this cultivar also in Brazilian regions, with high fruit quality (Fagherazzi, 2017). It is worth noting that although the genotype FRF PIR 075.08 stood out in terms of the average mass of its commercial fruits, it suffered greater influence of the color variables, causing it to remain allocated closer to the vectors of these variables, in relation to the vector of the AMCF variable.

It is also worth noting that the genotypes ITA 10.128.09, ITA 12.103.06, ITA 12.103.15, ITA 10.133.07, ITA 10.107.07, ITA 13.097.05, ITA 13.079.02, FRF PIR 256.04, and Pircinque were also strongly influenced by the SS/TA ratio vector, being responsible for producing fruits with better flavor balance, with SS/TA ratio well above the minimum expected value, which is 8.75 for strawberry fruits (Chitarra & Chitarra, 2005).

However, among the aforementioned genotypes, the fruits with the lowest titratable acidity contents were produced by the genotypes ITA 12.103.06, ITA 12.103.15, and ITA 10.133.07. Zanin (2019) found similar acidity values for genotype ITA 12.103.15, with 0.44 g 100g^{-1} of citric acid, however for genotype ITA 12.103.06, the author found higher values with 0.56 g 100g^{-1} of citric acid. In field analyses, the fruits of the genotype ITA 10.133.07 always presented excellent flavor, with balanced acidity and excellent sweetness, as we can see in laboratory analyses. Because it is a genotype resulting from the crossing of the cultivars Pircinque and Primoris, which have fruits with high flavor and sweetness (Medina et al., 2014), more balanced acidity contents were expected for this genotype.

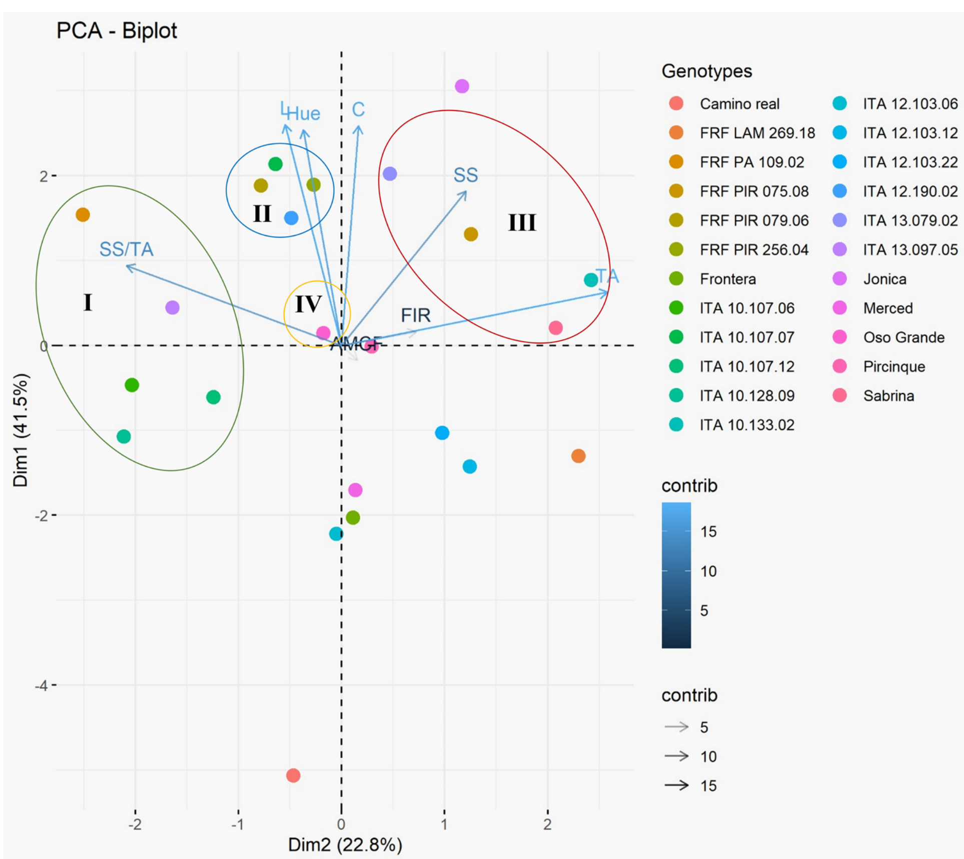
It is also worth mentioning that it was also in the genotype ITA 10.133.07 that the highest soluble solids/titulable acidity (SS/TA) ratio was verified, very similar to that also found for the genotype ITA 10.128.09, producing both, on average, fruits 27.9% sweeter than the general average, since the SS/TA ratio allows us to evaluate the flavor of the fruits (Backes et al., 2020). The genotype ITA 10.133.07 comes from a cross between two Italian cultivars, one of them being Pircinque, as previously described, which, despite not showing high SS/TA ratio values in this vintage, is widely known for the flavor and sweetness of its fruits (Faedi et al., 2014; Fagherazzi et al., 2017), a characteristic visibly inherited by this genotype. Zanin (2019) in a new genotype selection study also obtained high SS/TA ratio values for genotype ITA 10.128.09, with 14.33, very close to that found in the present study. We can see in this case the importance of quantifying not only the sugar content of a fruit, but also its acidity content, a parameter that influenced to a greater extent the SS/TA ratio of most genotypes, as we can see through the strength of the titratable acidity vector in the principal components analysis performed (Figure 1).

In the second cycle of cultivation 2019/2020, we had the insertion of new cultivars for comparison and also of genotypes, as well as the exclusion of some as is common in trials carried out within genetic improvement programs, when genotypes, already in an advanced stage, do not demonstrate sufficient positive characteristics to continue in the study.

In this harvest, by performing principal component analysis (Figure 2), we obtained the identification of mainly three groups for the short day genotypes.

Group I was formed by the genotypes FRF PA 109.02, ITA 10.107.06, ITA 10.128.09, ITA 10.107.12, and ITA 13.097.05. These genotypes correlated positively with the SS/TA ratio variable, a very important attribute for determining fruit flavor, since it corresponds to the balance between acidity levels and sugar concentration, thus the higher the SS/TA ratio, the greater their acceptance (Farnezi et al., 2020). These genotypes, then, present the fruits with the highest sensory quality and flavor balance.

It is worth noting then that the tastiest fruits, with the highest SS/TA ratio among the genotypes tested, were produced by the genotype ITA 10.128.09. However, the genotypes ITA 10.107.06, FRF PA 109.02, and ITA 10.107.12, also stood out regarding this parameter, having a variation of 6.54% among them (Table 3). It is worth noting that the genotype ITA 10.128.09 had already stood out regarding the SS/TA ratio in the previous harvest, demonstrating a good capacity to adapt to the study site. When fruit quality is evaluated, the SS/TA ratio is one of the most important ways to determine fruit flavor, being more representative than the isolated measurements of soluble solids and acidity, because it shows the balance between these two factors, necessary to have fruits with high flavor (Backes et al., 2020).



L - epidermis luminosity; C - epidermis chroma; Hue - epidermis Hue angle; SS - soluble solids; TA - titratable acidity; SS/TA - soluble solids/titratable acidity ratio; FIR - pulp firmness; AMCF - average mass of commercial fruits.

Figure 2. Principal component analysis for the short day genotypes and parameters studied in the fruit quality trial, in the 2019/2020 harvest in the municipality of Farroupilha, RS. Lages, SC, Brazil, Udesc, 2021.

Table 3. Average mass of commercial fruits (AMCF) (g fruit^{-1}), fruit pulp firmness (FIR) (g fruit^{-1}), epidermis luminosity (L*), epidermis chroma (C*), hue angle (°Hue), soluble solids (SS) (°Brix), titratable acidity (TA) (g 100g^{-1} of citric acid), soluble solids/titratable acidity ratio (SS/TA), of cultivars and advanced short day strawberry genotypes. Lages, SC, Brazil, Udesc, 2021.

2019/2020 harvest								
Genotype	AMCF	FIR	L*	C*	°Hue	SS	TA	SS/TA
Short day								
Jonica	19.69 c	139.82 e*	40.11 a	47.62 a	34.37 e	6.5 a	0.61 d	10.60 b
Pircinque	27.42 a	236.92 a	36.61 e	43.23 c	31.34 c	5.6 c	0.50 b	11.20 b
Camino real	19.64 c	134.77 f	31.39 g	35.45 e	26.27 a	4.4 d	0.45 a	9.60 c
Oso Grande	19.42 c	130.05 f	37.34 d	44.37 b	33.08 d	5.0 d	0.51 b	9.70 c
Merced	18.14 d	185.15 c	35.29 f	40.51 d	28.73 b	5.3 c	0.50 b	10.52 b
Fronteras	26.80 a	114.25 g	35.29 f	40.87 d	30.37 c	4.7 d	0.51 b	9.20 c
Sabrina	21.19 c	204.17 b	37.11 d	44.73 b	31.75 d	5.4 c	0.61 d	8.87 c
FRF LAM 269.18	23.40 b	146.27 e	34.96 f	42.32 c	29.12 d	5.6 c	0.63 d	8.85 c
FRF PIR 075.08	20.92 c	191.72 b	37.92 c	45.77 b	32.71 d	5.9 b	0.58 c	10.20 c
FRF PIR 256.04	23.09 b	110.32 g	38.94 b	47.03 a	33.41 e	5.9 b	0.53 b	11.10 b
FRF PA 109.02	25.57 a	156.27 d	40.02 a	46.58 a	34.17 e	4.9 d	0.40 a	12.22 a
FRF PIR 079.06	19.78 c	158.45 d	39.84 a	47.03 a	33.42 e	5.5 c	0.49 b	11.25 b
ITA 10.133.02	20.44 c	163.10 d	37.12 d	45.38 b	30.77 c	6.2 a	0.65 d	9.52 c
ITA 13.079.02	18.48 d	175.97 c	39.42 a	45.39 b	33.63 e	6.1 b	0.55 c	10.85 b
ITA 13.097.05	20.38 c	171.10 c	38.81 b	45.77 b	32.75 d	4.6 d	0.42 a	10.80 b
ITA 12.190.02	20.23 c	120.90 g	39.97 a	45.84 b	33.90 e	5.3 c	0.51 b	10.22 c
ITA 10.107.12	21.06 c	159.35 d	36.67 e	42.28 c	29.99 c	5.4 c	0.45 a	11.92 a
ITA 10.107.07	18.14 d	145.42 e	39.19 b	48.28 a	33.86 e	5.6 c	0.50 b	11.15 b
ITA 10.107.06	17.95 d	129.60 f	36.48 e	41.17 d	30.93 c	5.5 c	0.43 a	12.65 a
ITA 12.103.06	20.21 c	152.80 d	34.92 f	42.15 c	30.06 c	4.3 d	0.48 b	8.85 c
ITA 12.103.12	17.87 d	182.02 c	34.25 f	43.06 c	29.43 b	5.4 c	0.53 b	9.10 c
ITA 12.103.22	24.81 b	125.72 f	35.08 f	42.64 c	30.03 c	5.4 c	0.59 c	10.15 c
ITA 10.128.09	20.14 c	147.15 e	35.97 e	41.60 d	29.32 b	5.3 c	0.41 a	12.70 a
Overall average	21.08	155.71	37.07	43.87	31.45	5.4	0.51	10.48
CV (%)	6.66	7.19	1.64	2.12	3.04	6.01	6.10	8.84

* Means followed by the same letter in the column do not differ by the Scott-Knott test ($p \geq 0.05$).

In group II remained allocated the genotypes FRF PIR 256.04, ITA 10.107.07, ITA 12.190.02, and PIR 079.06, which correlated positively with the fruit color vectors. This result is due to the fact that most of these genotypes have presented the highest hue angle values, not tending towards dark red, but with a bright red coloration and high color saturation, resulting in fruits of high visual quality.

Therefore, in relation to these colorimetric characteristics of the fruits, the highest epidermis luminosities were obtained by the genotypes Jonica, FRF PA 109.02, FRF PIR 079.06, and ITA 12.190.02, which configured lighter fruits, however with a very vivid coloration, with high saturation, due to the high chroma contents also observed in most of these genotypes. The chroma was higher in the fruits of genotypes Jonica, FRF PIR 256.04, FRF PA 109.02, FRF PIR 079.06, and ITA 10.107.07, showing higher color purity. The distinct patterns of fruit coloration is an intrinsic characteristic of the genotype, i.e., a genetic response, and may in certain agricultural cycles be influenced by climatic and cultural factors (Castricini et al., 2017). It is worth noting that although the genotype FRF PA 109.02, presents high luminosity and chroma in its fruits, this genotype suffered greater influence from the SS/TA ratio vector, remaining allocated near the vector of this variable, thus composing group I.

In group III, the genotypes ITA 10.133.02, ITA 13.079.02, FRF PIR 075.08, and Jonica were allocated, which correlated positively to the SS vector, producing the fruits with the highest sugar contents. However, they also obtained a positive correlation with the titratable acidity vector, resulting in fruit with lower SS/TA ratios. Among them, the Jonica cultivar and the genotype ITA 10.133.02, obtained the highest sugar contents in their fruits, on average 17.6% higher than the general average obtained (Table 3). Jonica is an Italian cultivar, known for having high sugar content in its fruit (Morello, 2014). The genotype ITA 10.133.02, as well as the genotype ITA 10.133.07, which stood out in sweetness in the previous cycle, has as one of its genitors the cultivar Primoris, which also has high levels of soluble solids in its fruits (Medina et al., 2014). This characteristic is inherited by both materials, but visibly affected by the genotype factor. It is important to note that the genotype ITA 10.133.07, is not present in this harvest in question, due to a problem with seedling multiplication, and it is necessary to reevaluate the response of this genotype in more growing cycles, in this and other locations.

In this harvest cycle (2019/2020), the genotypes in general, showed low soluble solids contents if observed the previous harvest (2018/2019). A factor that may have influenced this context, may have been the change of the installation site of the experiment, within the producer property, which was installed in a greenhouse very close to large trees, which made the environment more shaded during periods of the day. When there is less sunlight on the fruit, there is a decrease in the accumulation of sugars in the tissues, a consequence of less intensity in the photosynthetic process, which ultimately compromises the sweetness of the fruit (Taiz et al., 2017).

What also drew attention in this study is that genotypes that usually present high contents of soluble solids such as the cultivars Pircinque and Sabrina, presented relatively low contents in both harvests when compared to other studies already conducted with them (Faedi et al., 2014; Ahmadi et al., 2017; Richter, 2018; Zanin, 2019). This makes clear the influence of the phenotype factor and also the management factor in the expression of the characteristics of each genotype.

It is worth noting that acidity contents were lower in the fruit of the genotypes Camino Real, FRF PA 109.02, ITA 13.097.05, ITA 10.107.12, ITA 10.107.06, and ITA 10.128.09, on average, 21.42% lower than the average obtained from all genotypes (Table 3). The titratable acidity parameter is an indication of the amount of organic acids present in the fruit, which when in balance with the sugar contents, confers flavor and makes it an important quality attribute (Farnezi et al., 2020). This low titratable acidity value, for some of the genotypes mentioned above, resulted in a higher SS/TA ratio, when compared to the other genotypes studied, as previously described.

Again in this cycle, the greatest influence on SS/TA ratio values was by acidity contents in the fruit, since sugar contents were relatively low overall. There are reports in the literature that the acidity content in the fruit throughout the harvest can change due to the increase in temperature and sun exposure, especially in summer, causing the internal temperature of the fruit to increase by up to 8 °C compared to the air temperature, increasing acidity levels for certain materials that tend to suffer more from high temperatures (Taghavi et al., 2019).

Group IV was formed only by the Pircinque cultivar, which, among all the genotypes, presented the best balance among all the qualitative characteristics evaluated, improving its quality in relation to the previous harvest. However, it suffered more positive influence from the firmness and AMCF vectors. It is worth noting that as well as the cultivar Pircinque also suffered a positive and moderate influence of the SS/TA vector. The genotype FRF PA 109.02 and the Sabrina cultivar were also influenced by the vector of the AMCF ratio variable, but did not remain close to this vector due to other variables influencing these genotypes more strongly.

It is also worth noting that although the average mass values found are not so high for these genotypes in general, the ability to produce fruits of excellent size by some of these genotypes has already been reported in the literature (Fagherazzi et al., 2012; Faedi et al., 2014; Cocco et al., 2017, 2020). We can also point out that the cultivars Pircinque and Sabrina had already correlated to this variable in the last harvest, maintaining, even under different climatic and handling conditions, the size of their fruits. Fruits of larger size are desired by producers to the detriment of an exacerbated number of fruits of smaller size, since, it facilitates the harvest, has better market acceptance and unburdens the production (Farnezi et al., 2020).

The cultivar Pircinque also stood out regarding the firmness of its fruits, differing from the other genotypes evaluated, with fruits 52.15% firmer than the general average firmness obtained (Table 3), surpassing the firmness obtained in the previous harvest. Fagherazzi et al. (2017) found a pulp firmness value of 373 g, which was even higher than the value obtained in this study. One of the attributes for which the Italian cultivar Pircinque was introduced in Brazil and gained consumer preference is the high firmness of its fruit (Fagherazzi et al. 2012), when compared to commercial cultivars, which was evident in this study.

Pulp firmness is a characteristic of great relevance in maintaining fruit quality, along with sugar content, acidity, and the SS/TA ratio, since fruit strength, determined by the pressure force that the fruit supports, increases shelf life, a very important factor in in natura commercialization, besides enabling transportation over long distances to distribution centers (Fagherazzi et al., 2012). Besides this, the firmness of the fruits may suffer variation according to the management adopted by the producer in the different agricultural cycles. An example of this is the Pircinque cultivar itself, which in the previous cycle did not show its characteristic firmness of pulp, which may have occurred due to excessive nitrogen fertilization used by the producer. Excess nitrogen can cause overgrowth of the vegetative part of the plants, leading to competition between fruits and leaves for calcium, thus decreasing the concentration of this nutrient in the fruits, due to the greater drainage strength of the leaves (Taiz et al., 2017).

The fruits of Pircinque also, presented the highest average mass among the genotypes, which was visible by its proximity to the AMCF vector, which had already occurred in the 2018/2019 harvest, however, with fruit mass very similar to that obtained by the genotype FRF PA 109.02, surpassing the average mass obtained by the fruits of the American commercial cultivars used as a comparison. This result is opposite to that verified by Zanin et al. (2019), who obtained an average mass for the fruits of Pircinque and genotype FRF PA 109.02 of 20.81 and 20.66 g fruit^{-1}, respectively, not surpassing the average values obtained by the commercial cultivars used as comparison in the study by the authors. In visual and tactile evaluations carried out in the field, during the production cycle, both genotypes have always demonstrated an expressive quality of their fruits, which is now proven by laboratory analyses.

Fruit fresh mass is a very relevant characteristic in commercial strawberry production, since it is directly related to the size of the fruit, as previously pointed out. Large fruits tend to facilitate harvesting and packing, optimizing labor, besides having a higher market valuation, increasing the producer earnings (Farnezi et al., 2020). In the 2019/2020 crop cycle, the growing site and umbrella-shaped cover enabled the plants to maintain temperature compared to the low tunnels used in the previous cycle, which promoted the production of larger and better quality fruit by the plants (Gonçalves et al., 2016).

Conclusions

Under the environmental conditions of the study, the cultivar Pircinque and the genotype FRF PIR 075.08 produce fruits with good firmness and high visual quality.

The Jonica cultivar, and the genotypes FRF PIR 256.04, FRF PIR 075.08, ITA 10.107.07 FRF PIR 079.06, and ITA 13.079.02 produce fruits with high visual quality, with more balanced red coloration, high brightness and high color saturation.

The genotypes Pircinque and ITA 10.128.09 maintained good fruit flavor in both harvests, with high SS/TA ratio averages, making them promising for the consumer market.

Among the genotypes evaluated for the Farroupilha region, SC, Brazil, the genotypes FRF PIR 075.08 and ITA 10.128.09 have the greatest potential to become cultivars and, together with the Pircinque cultivar, may be recommended for cultivation in the Serra Gaucha region.

Compliance with Ethical Standards

Author contributions: Conceptualization: PDW, AAK. LR; Data curation: PDW, MFSS, DPR, LR; Formal analysis: PDW, MFSS, DPR; Investigation: PDW, JML, MFSS; Metodology: PDW, JML, MFSS; Project administration: AAK. LR; Resources: AAK. LR; Supervision: AAK. LR; Validation: AAK, LR, DPR; Visualization: AAK, LR, PDW; Writing - original draft: PDW, DPR; Writing - review and editing: AAK, LR, DPR.

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