Original Research Article

Productive Performance and Fruit Quality of Short Days Italian Genetic-based Strawberry Cultivars and Genotypes in Southern Brazil

ABSTRACT

When grown under different climatic conditions, short days Italian genetic-based strawberry (IGBS) cultivars and genotypes present variations in productive performance and fruit quality. The objective of this study was to assess different productive performance and fruit quality of IGBS cultivars and genotypes grown in highland regions of southern Brazil. The experiments were conducted in randomized blocks using three cultivars and 21 genotypes during the 2019, 2020 and 2021 growth seasons. The data were subjected to multivariate analysis using principal component analysis (PCA). IGBS cultivars and genotypes differed significantly in terms of productive and fruit quality parameters, according to PCA data. The first and second main components of PCA, respectively, were responsible for 61.9% and 72.4% of the productive performance and fruit quality parameters. The Pircinque cultivar and FRF PIR 256.04, ITA 13.097.05, ITA 12.103.22, ITA 10.107.07, and ITA 10.133.02 genotypes showed the highest indices of productive parameters of total production per plant, commercial production per plant, total fruit number per plant and commercial fruits number per plant. Among these, the Pircinque cultivar and the FRF PIR 256.04 genotypes demonstrated the best fruit quality parameters of fruit color (skin luminosity, chroma, and hue angle), flavor (soluble solids/ titratable acidity ratio), and fresh commercial fruit mass in highland regions of southern Brazil during the 2018, 2019 and 2020 growth seasons.

***Keywords**:* *Fragaria* x *ananassa* Duch., Agronomic performance, Adaptability, Yields, Productivity.

Comment [VA1]: Experiment

Comment [VA2]: Block design

Comment [VA3]: yield

1. INTRODUCTION

In the last 20 years, global strawberry (*Fragaria* x *ananassa* Duch.) production has more than doubled to over 3.6 million tons. The Northern Hemisphere accounts for (98%) of production, with genetic and climatic barriers preventing expansion to the south hemisphere (Faostat, 2021). Strawberry crop development in Brazil began in the mid-1960s, with the launch of the Campinas cultivar (Heide et al., 2013), and production of the crop has increased in the country since then. Currently, production is around 165,000 tons in about 4,500 hectares of cultivated land, with an average productivity of 36.6 tons per hectare (Faostat, 2021).

Strawberry cultivation progress is linked to the introduction of new cultivars to the market, improvement of cultivation techniques and systems, as well as climatic adaptation. Strawberry cultivation has been concentrated primarily on family properties in southern Brazil, particularly in temperate and subtropical regions (Fagherazzi et al., 2014).

Currently, national strawberry production is almost entirely dependent on imported cultivars from the University of California, United States of America (USA) strawberry breeding programs. Many of these cultivars, however, are grown without any prior research into climatic adaptation and productive requirements for different producing regions in southern Brazil. Brazil has a diverse climate and can produce strawberries almost every month of the year. However, due to the country's edaphoclimatic diversity, the small number of available cultivars has been one of the main barriers to the development of the strawberry crop. National breeding programs are essential for encouraging the development and introduction of new cultivars developed in other countries (Oliveira & Scivittaro, 2009).

A cultivar's climatic adaptation to a specific producing region is expressed through the interaction among genotype, environment, and genetic feature, which influences production, productivity, and fruit quality. Thus, the responses of cultivars to fruit yield and quality are primarily determined by the interaction of two factors, photoperiod and temperature (Camargo et al., 2010).

Adaptability studies of cultivars and genotypes are extremely important and necessary, not only in new producing regions, but also in traditional ones, which often, for cultural reasons, do not seek new cultivars that enable better agronomic performance, which is essential for producers' decision-making regarding the best material to be grown in different regions (Guimarães et al., 2015).

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As a result, the adaptability study with short days Italian genetic-based strawberry cultivars and genotypes in southern Brazil regions is important for obtaining new materials, increasing the cultivars offer in the producing market, and materials that are more productive and have better fruit quality. Thus, the objective of this study was to assess the productive performance and fruit quality of short days Italian genetic-based strawberry cultivars and advanced genotypes grown under edaphoclimatic conditions in highland regions of southern Brazil during the 2019, 2020, and 2021 growth seasons.

2. MATERIALS AND METHODS

The experiments were conducted in Lages Municipality (27°47'05'' S, 50°18'08'' W), at an altitude of 922 m above sea level, in Santa Catarina State, Southern Brazil, during the 2019, 2020 and 2021 growth seasons. According to Köppen classification, the climate of the region is subtropical humid mesothermal Cfb, and soil type is Clay Auric Cambisol (Santos et al., 2013). The average annual temperature and rainfall are around 15.6 ºC and 1,500 mm, respectively. Daily rainfall, relative humidity, and hourly temperatures were recorded from May to December of the 2019, 2020, and 2021 growth seasons by the Santa Catarina Hydrology and Environmental Resources Center (Epagri). The weather station (Onset Computer Corp., Procasset, MA, USA; Davis Pro2-6153) was 500 m away from the vineyard.

Comment [VA5]: Mention the seasons in month

The experiments included 24 treatments involving three Spanish and Italian cultivars and 21 Italian short days genetic-based genotypes from Consiglio per la Ricerca in Agricoltura-Centro di Olivicoltura, Frutticoltura e Agrumicoltura – CREA-OFA/Italy and Santa Catarina State University (UDESC). Strawberry seedlings used in all experiments were grown field-collected stolon's and rooted in 72 cells trays in a commercial nursery in the Farroupilha Municipality of Rio Grande do Sul State, southern Brazil. The cultivars Jonica, Sabrina, and Pircinque, and the genotypes FRF LAM 269.18, FRF PIR 075.08, FRF 256.04, FRF LAM 263.01, FRF PA 109.02, FRF PIR 079.06, ITA 10.133.02, ITA 13.079.01, 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 12.103.04, ITA 12.103.06, ITA 12.103.12, ITA 12.103.15, ITA 10.103.22, ITA 10.128.06, and ITA 10.128.09 were evaluated.

A conventional soil cultivation system in low tunnels was used in an experimental randomized blocks design with four replications and eleven plants in each experimental unit. Strawberry seedlings were planted by hand beginning in May of each year of 2019, 2020, and 2021. Soil correction and fertilization were carried out in accordance with soil analysis (SBCS, 2016). Fertilization was done weekly with fertigation, which included: calcium nitrate (9.92 g/100 plants^{-1}); monoamonic phosphate (38.74 g/100 plants^{-1}), P51 (liquid fertilizer containing 51% phosphorus) (7.3 mL/100 plants^{-1}); magnesium sulfate (4.55 g/100 plants^{-1}), and potassium phosphate (31.25 g/100 plants^{-1}).

The experimental beds were approximately 1.00 × 27 × 0.20 m in size for each cultivar and genotype (L × C × H). The beds were covered with 30-micron thick black polyethylene plastic ('mulching'). Strawberry plants were grown in three rows in a "V" or quinconic system, with 30 cm between plants and 60,000 plants per ha. The irrigation system was drip, with 0.15 m spacing between drippers and a flow rate of 1.5 liters per hour, with three hoses per bed.

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When necessary, pest and disease control was carried out using crop-specific products. Acaricide abamectin, insecticide thiametoxan, and fungicides methyl thiophanate (only before harvest), fluazinam, iprodione, pyrimethanil, and azoxystrobin + diphenoconazole were also used. Weeds were controlled by weeding between the beds and manual tillage in the planting pits, and old and diseased leaves were removed with pruning shears.

Beginning at the end of August and lasting until the middle of February the following year, harvests were carried out every three days when the fruits displayed epidermis with approximately 70%–80% of the red color. Strawberry fruits were counted, weighed on a semi-analytical scale, and classified using the following criteria:

Comment [VA7]: harvest

1) Commercial fruits are those that weight more than or equal to 10 grams and are free of injuries, deformations, or rots;

2) Small fruits weighing less than 10 grams and free of injuries, deformations, or rots;

3) Discarded fruits are those with injuries, deformations, or rots.

2.1 Productive parameters

The following productive parameters were quantified using the number and weight of analyzed fruits.

a) total plant production (TPP) (g/plant^{-1}); b) commercial production per plant (CPP) (g/plant^{-1}); c) total productivity (TPT) (t/ha^{-1}); d) commercial productivity (CPT) (t/ha^{-1}); e) number of total fruits per plant (NTF) (fruits/plant^{-1}); f) number of commercial fruits per plant (NCF) (fruit/plant^{-1}); g) percentage of commercial production (PCP) (%); h) percentage of small fruit per plant (PSF) (%); and, i) percentage of discard fruits per plant (PDF) (%).

2.2 Fruit quality parameters

The following fruit quality parameters were quantified using the number and weight of analyzed fruits.

a) fruit pulp firmness (FPF) (g/fruit^{-1}); b) epidermis luminosity (L*); c) epidermis chroma (C*); d) hue angle (°hue); e) soluble solids (SS) (°Brix); (f) titratable acidity (TA) (g. 100g citric acid); g) soluble solids/titratable acidity ratio (SS/TA); h) average fresh mass of commercial fruits (AMCF) (g/fruit^{-1}).

The physicochemical analysis was carried out using uniform samples of ten fruits per repetition, at each new plant flowering, for a total of four analyses per plant productive cycle. The physicochemical analyses were carried out in accordance with the following methodologies:

a) Texture Analyzer TA texturometer (Stable Micro Systems Ltd., Vienna Court, UK) was used to measure the L*, C*, °hue (color angle), and FPF parameters expressed in grams;

b) SS are measured using a digital refractometer and expressed as the concentration of sugars in fruits (°Brix); TA is measured using an automatic TITRONIC titrator® with 5 mL of juice in 45 mL of distilled water and titration in sodium hydroxide solution 0.1N at pH 8.1; and the SS/TA ratio was calculated as the ratio of SS content and TA.

2.3 Data analysis

The analyses were carried out with data from harvests in 2019, 2020, and 2021, and were carried out by the Shapiro-Wilk normality test, using the Software R (R Cor Team, 2013), via the Action Stat interface. The univariate analysis was carried out using analysis of variance and a scott knott test with a 5% probability of error using the statistical program SISVAR (Ferreira, 2011). Fitopac 2.1's statistical program used the PCA for the multivariate analysis (Shepherd, 2010).

Comment [VA8]: harvest

3. RESULTS

The Pircinque cultivar and FRF PIR 256.04, ITA 10.133.02, ITA 13,097.05, ITA 10.107.07, and ITA 12,103.22 genotypes were significantly more productive and had higher fruit quality. The Pircinque cultivar and the FRF PIR 256.04, ITA 10.133.02, ITA 13,097.05, ITA 10.107.07, and ITA 12,103.22 genotypes had a significant influence on the productive parameters of CPP, NTF, NCF and, AMCF, as well as the fruits quality parameters of L, C*, °hue, SS (°Brix), and SS/TA ratio. The Pircinque cultivar and the FRF PIR 256.04, ITA 10.133.02, ITA 13.097.05, ITA 10.107.07, and ITA 12,103.22 genotypes did not show significant differences in fruit quality parameters, which were related to the sweet taste of the fruits and considered very promising cultivar and genotypes for the Brazilian market (Table 1).

The Pircinque and Sabrina cultivars and the FRF PIR 256.04 and ITA 12.103.22 genotypes, produced significant fruits with high FPF and SS and were found to be positively related to the fruits quality parameters L, C, °hue, and SS/TA, indicating fruits with higher sugar content (Table 1). The Pircinque and Sabrina cultivars and the FRF PIR 256.04, ITA 10.107.07, and ITA 12,103.22 genotypes, produced significantly higher-quality fruits with SS/TA ratios that were 25% higher on average than the other cultivars and genotypes, indicating high tasty fruits (Table 1).

Figures 1 and 2 depicted the PCA data of the cultivars and genotypes productive and fruit quality parameters, respectively. The PCA data of all harvests occurring during the 2019, 2020, and 2021 growth seasons revealed, via vectors, the formation of two major groups of cultivars and genotypes with a positive correlation with productive and fruit quality parameters.

In Figure 1, both main components were responsible for 85.4% (61.9% plus 23.5%) of the cultivars and genotypes differentiation, according to productive parameters. According to TPP, CP, NTF, and NCF productive parameters, the first main component was responsible for 61.9% of the differentiation of cultivars and genotypes. Thus, the Pircinque cultivar and the FRF PIR 256.04, ITA 13.097.05, ITA 12.103.22, ITA 10.107.07, and ITA 10.133.02 genotypes, highlighted in Figure 1, were differentiated by showing the highest productive parameters and consequently, more productive plants. The second main component was responsible for 23.5% in the cultivars and genotypes differentiation, according to PSF and PDF productive parameters. Thus, the Pircinque cultivar and the FRF PIR 256.04, ITA 13.097.05, ITA 12.103.22, ITA 10.107.07, and ITA 10.133.02 genotypes, highlighted in Figure 1, were differentiated by the fruit classification, considered non-commercial fruits because they are either small or discard fruits. The Pircinque cultivar and the FRF PIR 256.04 genotype produced more discarded fruits than small fruits per plant, whereas the ITA 10.107.07 and ITA 10.133.02 genotypes produced more small fruits than discarded fruits per plant.

In Figure 2, both main components were responsible for 72.5% (46.4% plus 26.1%) of the cultivars and genotypes differentiation, according to fruit quality parameters. According to fruit color L*, C*, and °hue, the first main component was responsible for 46.4% of cultivars and genotypes differentiation. According to fruit flavor SS/TA and AMCF parameters, the second main component was responsible for 26.1% of the differentiation between cultivars and genotypes. The FPF did not show significance for any of the main components (first and second) and was not regarded as a good and reliable parameter in the differentiation of cultivars and genotypes.

The Pircinque cultivar and FRF PIR 256.04, ITA 13,097.05, ITA 12.103.22, ITA 10.107.07, and ITA 10.133.02 genotypes showed the highest productive parameters of CPP, TPP, NCF and NTF (Figure 1). Among them, the Pircinque cultivar and FRF PIR 256.04 and ITA 12.103.22 genotypes, highlighted in Figure 2, demonstrated the highest color, flavor, and AMCF parameters, with the highest value for the Pircinque cultivar and FRF PIR 256.04 genotype. Despite having high productive parameters, the ITA 13.097.05, ITA 12.103.22, and ITA 10.133.02 genotypes showed significantly lower fruit color parameters when compared to the Pircinque cultivar and FRF PIR 256.04 and ITA 12.103.22 genotypes that differed by the SS/TA and AMCF parameters. However, the ITA 13.097.05 genotype showed the highest SS/TA and AMCF, indicating a high sweet taste than ITA 12.103.22 and ITA 10.133.02 genotypes (Figure 2).

4. DISCUSSION

The Pircinque cultivar and FRF PIR 256.04, ITA 10.133.02, ITA 13.097.05, ITA 10.107.07, and ITA 12.103.22 genotypes showed a positive correlation between the productive and fruit quality parameters. This correlation is highly desirable because cultivars and genotypes that combine high production and sweet fruit quality are difficult to find. These findings are consistent with Zanin et al. (2019), who identified these cultivars and some of these genotypes for production in some regions of southern Brazil and other climate areas. The Pircinque cultivar and FRF PIR 256.04, ITA 10.133.02, ITA 13.097.05, ITA 10.107.07, and ITA 12.103.22 genotypes demonstrated high NTF and AMCF, which are important parameters for strawberry yield (Oliveira & Bonow, 2012).

Strawberry fruit size stability is an important criterion in the plant breeding selection process for new commercial cultivars. Thus, the AMCF parameter is directly related to fruit size, because large fruits facilitate harvesting and packaging, lowering production and general service costs (Fagherazzi et al., 2014).

The TPT average of the Jonica and Pircinque cultivars, as well as the FRF PIR 256.04 and ITA 12.103.22 genotypes, was 24.35 t ha^{-1}, which was higher than the world TPT average of 22.7 t ha^{-1} (Table 1) (Fao, 2018). The ITA 12.103.22 genotype progeny (parents) is the cultivar “Florida Fortuna” which has high production, productivity and fruit quality (Whitaker et al., 2015). Zanin et al. (2019) obtained better results with these same materials in a conventional system in the Santa Catarina State highland region of southern Brazil. The Jonica cultivar progeny is the “Kilo”, a high productive cultivar that was also chosen for its early production and productivity when compared to the other cultivars and genotypes, as these characteristics can increase its productive potentiality and agronomic performance (Ariza et al., 2012; Faedi et al., 2009).

The Italian Pircinque cultivar, introduced in Brazil by the Santa Catarina State University (UDESC), had previously been evaluated and demonstrated a high degree of climate adaptability to the regions of southern Brazil (Faedi et al., 2014, Zanin et al., 2019). The FRF PIR 256.04 genotype was developed as part of a strawberry breeding project developed at CREA-OFA/Italy with the goal of creating a series of strawberry cultivars with high fruit yield and quality. The FRF PIR 256.04 genotype was previously evaluated in Brazil by Faedi et al (2014), and it high productive performance, good environmental response, and visual fruit quality are supported by the current data.

The Pircinque cultivar and the FRF PIR 256.04, ITA 10.133.02, ITA 13.097.05, ITA 10.107.07, and ITA 12.103.22 genotypes demonstrated a high NTF and AMCF of 18.47 grams. Otto et al (2009) defines an excellent commercial fruit quality as an AMCF parameter of around 12.0 grams per fruit. Additionally, this former cultivar and genotypes group (Pircinque cultivar and FRF PIR 256.04, ITA 10.133.02, ITA 13.097.05, ITA 10.107.07, and ITA 12.103.22 genotypes), showed the highest fruit red color intensity, especially by the L* parameter, because L* parameter expresses the degree of color luminosity (L* = 100 = white; L* = 0 = black). In this case, the red values showed by this group, indicated the tendency of the fruits to light red color. The reduction of C* values indicate a reduction in the saturation of fruit red pigments, which is less vivid, while the color intensity values (°hue) indicated that the red color of the fruits remained similar among the cultivar and genotypes. According to Ávila et al. (2012), lower relative of °Hue values, indicate darker coloration. Thus, in the present study, the Pircinque cultivar and the FRF PIR 256.04, ITA 10.133.02, ITA 13.097.05, ITA 10.107.07 and ITA 12.103.22 genotypes showed high luminosity and consequently, light epidermis color. The fruit red external color is one of the first factors that consumers take into account in the acquisition of strawberry fruits. Fruits with intense bright red color, but not darkest, are preferable to the public consumers (Carpenedo et al., 2016). The epidermis luminosity (L*) can range from 0 (dark) to 100 (light), instead in the case of C* or also color purity, the lower of C* value, higher is the degree color impurity and lower the pigments saturation, while high C* values increase pigment saturation, generating a pure color (Castricini et al., 2017).

The Pircinque and Sabrina cultivars, as well as the FRF PIR 079.06, FRF PIR 256.04, and FRF PIR 075.08 ITA 12.103.22 genotypes, had the highest fruit SS concentrations, a quantitative feature that may be influenced by climate conditions (Pinelli et al., 2011; Costa et al., 2019). Plant photosynthesis generates SS with at least 85% sugars in their composition. The higher the SS content, the sweeter are the fruits (Ariza et al., 2012). The SS content is determined by genetic characteristics (Cocco et al, 2015; Pinelli et al., 2011) and is influenced by climate conditions, which explains the differences observed among the cultivars and genotypes studied. Strawberry SS contents variation range from 4.0°–11.0°Brix (Pinelli et al., 2011), and all data presented in this study fell within this range.

Pircinque and Sabrina cultivars and the FRF PIR 075.08, ITA 10.107.07 and ITA 12.103.22 FRF PIR 075.08, ITA 10.107.07, and ITA 12.103.22 genotypes, demonstrated the highest SS/TA ratio and, as a result, high fruits sweetness, correlating with the data obtained by Fagherazzi et al. (2016) and Ahmadi et al. (2017), particularly with Pircinque and Sabrina cultivars conducted under different nutritional management. A high SS/TA ratio reflects the quality of fruit flavor/aroma, which is the result of the fruit's sugar content and acidity being balanced. As a result, the higher the fruit SS/TA ratio, the more balanced the flavor/aroma and the greater the sensory fruit acceptance (Kader, 2002; Barankevicz et al., 2015). The fruit SS/TA ratio is more representative than sugars and acidity alone, allowing for a more accurate assessment of fruit flavor/aroma (Souza et al., 2019).

Pircinque cultivar and the FRF PIR 256.04, ITA 10.133.02, ITA 13.097.05, ITA 10.107.07, and ITA 12.103.22 genotypes produced not only a large number of fruits, but also a large number of marketable fruits with ideal size and visual quality, making these cultivar and genotypes potential options for commercial fresh fruits. When it comes to purchasing decisions, most consumers prioritize fruit size and appearance over flavor (Zanin et al., 2019). When developing new cultivars in breeding programs, genotypes that combine fruit quality characteristics with high productivity are always sought. However, this combination is not always easy to achieve, because many of these productive and fruit quality parameters are inversely related depending on the germplasm material available (Faedi et al., 2015).

5. CONCLUSION

The Pircinque cultivar and FRF PIR 256.04, ITA 10.133.02, ITA 13.097.05, ITA 10.107.07, and ITA 12.103.22 genotypes demonstrated the highest productive and fruit quality parameters in conventional soil systems at low tunnels in edaphoclimatic conditions of highland regions of southern Brazil.

The Pircinque cultivar and FRF PIR 256.04, ITA 10.133.02, ITA 13.097.05, ITA 10.107.07, and ITA 12.103.22 genotypes are potential options for producing cultivars with a high productive parameters, fruit flavor/aroma quality, and fruits SS/TA ratio for the *in natura* market.

The FRF PIR 256.04, ITA 10.133.02, ITA 13.097.05, ITA 10.107.07, and ITA 12.103.22 genotypes were the most promising in terms of fruit production and fruit quality features and may become cultivars recommended for cultivation in southern Brazil, along with Pircinque cultivar.

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Table 1. Analysis of variance (ANOVA) of productive parameters of a) total production per plant (TPP) (g plant^{-1}); b) commercial production per plant (CPP) (g plant-1); c) total productivity (TPT) (t ha-1); d) commercial productivity (CPT) (t ha^{-1}); e) number of total fruits per plant (NTF) (fruits/plant^{-1}); f) number of commercial fruits per plant (NCF) (fruit/ plant^{-1}); g) percentage of commercial production (PCP) (%); h) percentage of small fruit production (PSF) (%); i) percentage of discard fruits (PDF) (%), and fruit quality parameters of a) fruit pulp firmness (FPF) (g fruit^{-1}); b) epidermis luminosity (L*); c) epidermis chroma (C*); d) hue angle (°hue); e) soluble solids (SS) (°Brix); (f) titratable acidity (TA) (g/100g citric acid) and, g) soluble solids/titratable acidity ratio (SS/TA); h) average fresh mass of commercial fruits (AMCF) (g fruit^{-1}), of experiments conducted with short days Italian genetic-based strawberry cultivars and genotypes, during the 2019, 2020 and 2021 growth seasons, at the Lages/SC Municipality, southern Brazil.

Cultivars/genotypes	TPP	CPP	TPT	CPT	NTF	NCF	AMCF	FPF	PSF(%)	PDF(%)	PD(%)	L*	C*	°hue	SS	TA	SS/TA
Jonica	392,58* a	208,32 b	23,55 a	12,50 b	28,05 b	13,30 b	15,65 b	222,56 b	52,57 e	11,87 c	35,57 d	35,24 b	41,77 d	32,47 d	6,6 b	0,48 c	13,80 b
Pircinque	398,99 a	263,43 a	23,94 a	15,80 a	31,45 a	14,95 a	19,00 a	293,63 a	75,32 a	6,57 a	18,07 b	38,11 a	47,70 a	22,13 a	7,8 a	0,41 a	16,87 a
Sabrina	296,04 c	122,17 c	11,76 d	7,33 d	13,15 d	6,71 d	18,57 a	321,72 a	62,55 c	6,62 a	30,80 d	35,14 b	42,08 c	27,70 a	7,9 a	0,47 c	16,46 a
FRF LAM 269.18	337,50 b	219,94 b	20,25 b	13,19 b	22,53 c	11,45 b	19,32 a	193,22 c	65,15 c	5,35 a	29,55 d	33,86 c	41,16 d	29,95 b	7,2 b	0,54 d	13,27 b
FRF PIR 075.08	331,33 b	218,49 b	19,87 b	13,11 b	25,31 b	13,18 b	16,52 b	241,08 b	65,70 c	8,07 b	26,22 c	34,83 b	43,63 c	31,06 c	7,8 a	0,58 e	13,65 b
FRF PIR 256.04	412,66 a	279,43 a	24,76 a	16,79 a	32,88 a	15,11 a	18,95 a	282,30 a	67,95 c	5,17 a	26,90 c	37,16 a	46,18 a	21,73 a	7,9 a	0,38 a	16,07 a
FRF LAM 263.01	264,90 c	170,12 c	15,89 c	10,20 c	23,63 c	11,39 b	15,27 b	220,29 c	63,82 c	12,70 c	23,47 c	34,57 c	39,69 e	32,70 d	5,8 c	0,51 c	11,47 c
FRF PA 109.02	366,25 b	216,35 b	21,97 b	12,97 b	28,14 b	12,02 b	18,12 a	218,82 c	58,97 d	9,32 b	31,72 d	33,56 c	39,71 e	31,33 c	6,5 b	0,44 b	13,84 b
FRF PIR 079.06	276,19 c	164,54 c	16,57 c	9,87 c	20,37 c	9,32 c	17,42 a	197,06 c	58,77 d	8,15 b	33,07 d	38,60 a	46,87 a	34,87 e	8,2 a	0,67 e	13,38 b
ITA 10.133.02	377,73 a	273,61 a	19,06 b	13,41 b	28,67 a	14,87 a	17,41 a	228,79 c	70,35 b	13,60 c	16,05 b	34,34 c	40,86 d	30,80 c	6,8 b	0,70 e	9,54 c
ITA 13.079.01	179,59 d	81,95 d	10,77 d	4,91 e	16,67 d	5,04 e	16,21 b	247,90 b	45,67 f	14,95 c	39,35 d	35,13 b	43,09 c	33,92 e	6,8 b	0,67 e	10,06 c
ITA 13.079.02	228,35 c	143,49 c	13,69 c	8,61 c	21,63 c	9,25 c	15,56 b	263,93 b	63,00 c	25,40 d	11,60 a	35,58 b	41,00 d	33,74 e	5,4 c	0,57 d	9,39 c
ITA 13.097.05	388,22 a	262,10 a	22,09 b	13,92 b	29,86 a	15,07 a	17,87 a	164,41 d	63,10 c	7,72 b	29,20 d	34,03 c	42,23 c	32,15 d	4,9 d	0,45 b	10,74 c
ITA 12.190.02	75,49 e	49,05 e	4,53 e	2,94 f	6,16 e	3,14 f	15,84 b	98,40 e	64,90 c	9,97 b	25,15 c	39,30 a	44,39 b	34,90 e	5,8 c	0,54 d	10,81 c
ITA 10.107.12	250,47 c	147,60 c	15,02 c	8,85 c	20,84 c	7,83 d	18,66 a	249,62 b	58,42 d	19,10 d	22,50 c	34,02 c	40,10 e	31,18 c	4,6 d	0,39 a	11,60 c
ITA 10.107.07	391,36 a	284,30 a	21,68 b	13,46 b	29,55 a	13,99 a	18,78 a	153,04 d	61,95 c	15,47 c	22,55 c	39,27 a	47,80 a	20,85 a	4,8 d	0,35 a	15,82 a
ITA 10.107.06	242,83 c	157,09 c	14,57 c	9,42 c	18,01 d	8,85 c	17,56 a	153,93 d	63,97 c	12,07 c	23,90 c	32,06 d	38,42 e	29,63 b	5,7 c	0,45 b	12,87 b
ITA 12.103.04	252,19 c	143,78 c	15,13 c	8,62 c	20,31 c	8,84 c	16,17 b	212,86 c	56,82 d	9,00 b	34,17 d	30,94 d	40,47 d	27,66 a	5,7 c	0,52 c	11,07 c
ITA 12.103.06	209,75 c	168,33 c	12,58 c	10,09 c	13,75 d	9,19 c	18,23 a	235,67 b	79,67 a	9,47 b	10,85 a	30,64 d	38,33 e	26,62 a	5,4 c	0,49 c	10,86 c
ITA 12.103.12	174,98 d	109,91 d	10,50 d	6,59 d	14,35 d	6,33 d	17,39 a	266,44 b	63,00 c	15,80 c	21,25 c	33,66 c	43,35 c	30,85 c	4,6 d	0,43 b	10,63 c
ITA 12.103.15	315,13 b	201,20 b	18,90 b	12,07 b	20,25 c	10,27 b	19,68 a	192,92 c	63,85 c	6,45 a	29,67 d	33,23 c	42,62 c	30,93 c	5,4 c	0,47 c	11,46 c
ITA 12.103.22	419,13 a	292,15 a	25,14 a	17,53 a	30,75 a	18,35 a	17,97 a	304,23 a	69,52 b	11,85 c	18,62 b	36,34 a	46,19 a	25,79 a	7,6 a	0,40 a	16,62 a
ITA 10.128.06	258,77 c	188,78 c	15,52 c	11,32 c	24,33 c	11,65 b	12,44 c	251,65 b	72,90 b	11,22 c	15,87 b	33,96 c	40,60 d	32,09 d	5,9 c	0,54 d	10,78 c
ITA 10.128.09	267,68 c	169,83 c	16,06 c	10,18 c	19,60 c	9,08 c	18,87 a	214,73 c	63,35 c	8,62 b	28,07 c	33,84 c	39,46 e	31,93 d	6,2 c	0,52 c	11,75 c
Average	284,98	181,78	17,09	17,44	21,82	10,61	17,31	220,33	63,46	10,89	25,64	34,23	41,76	31,24	6,2	0,52	12,22
C.V*. %**	13,17	3,45**	13,17	7,64**	6,86**	7,78**	3,73**	9,93	6,81	9,36**	5,24**	3,14	2,99	3,21	7,97	2,82**	8,53

* Means followed by the same letter in the column are not significantly different (Scott-knott test, $P < 0.05$);

** Data transformed by the formula $Y = \log(x)$;

*** Coefficient of variation.

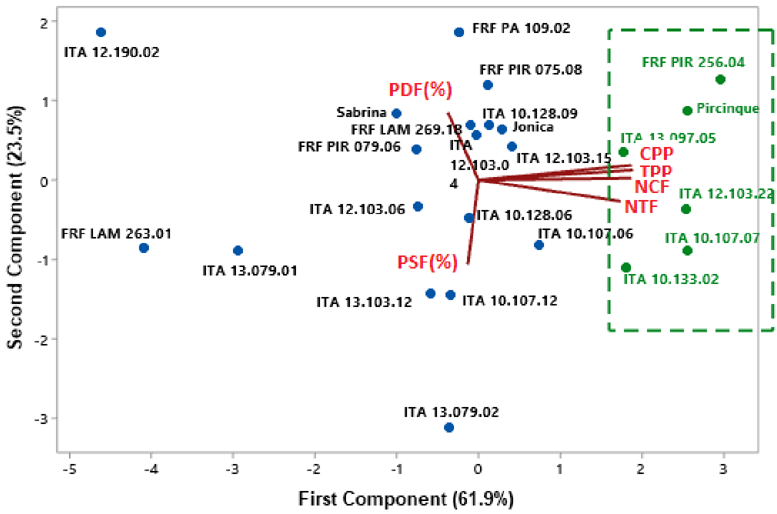

Figure 1- Principal Component Analysis (PCA) of the productive parameters of a) total production per plant (TPP) (g/plant^{-1}); b) commercial production per plant (CPP) (g/ plant^{-1}); c) number of total fruits per plant (NTF) (fruits/plant^{-1}); d) number of commercial fruits per plant (NCF) (fruit/ plant^{-1}); e) percentage of small fruit production per plant (PSF) (%), and, f) percentage of discard fruits per plant (PDF) (%) of experiments conducted with short days Italian genetic-based strawberry cultivars and genotypes, during the 2019, 2020 and 2021 growth seasons, at the Lages/SC Municipality, southern Brazil.

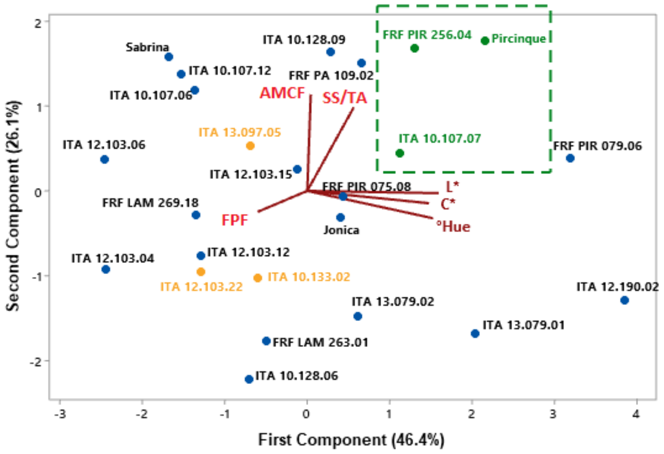

Figure 2 - Principal Component Analysis (PCA) of the fruit quality parameters of a) fruit pulp firmness (FPF) (g/fruit^{-1}); b) epidermis luminosity (L*); c) epidermis chroma (C*); d) hue angle (°hue); e) soluble solids/titratable acidity ratio (SS/TA), and f) average fresh mass of commercial fruits (AMCF) (g/fruit^{-1}) of experiments conducted with short days Italian genetic-based strawberry cultivars and genotypes, during the 2019, 2020 and 2021 growth seasons, at the Lages/SC Municipality, southern Brazil.