Agronomic performance of cultivars and advanced selections of strawberry in the South Plateau of Santa Catarina State[1]

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ABSTRACT

Strawberry cultivation requires the use of cultivars adapted to the temperature and photoperiod conditions of the production region. The objective of this work was to evaluate cultivars and advanced selections of strawberry on productive performance and fruit quality, under the conditions of South Plateau of Santa Catarina State. The experiment was carried out in the municipality of Lages, in the 2016/2017 growing season. The cultivation system used was in the soil, in beds covered with black polyethylene film. The cultivars Camino Real, Benicia and Pircinque, and the selection CE 56 obtained the highest yields, above to 30 t ha^{-1}. Benicia, Camino Real and Monterey, in turn, obtained the fruits with higher average fresh weight, around 24 g fruit^{-1}. In the selections CE 51, CE 56, FRF 57.6, LAM 119.1, FRF 104.1, FRF PA 109.2 and the cultivars Benicia and Monterey the fruits of better quality were achieved, expressed by values of soluble solids / titratable acidity ratio above to 13. The cultivars Camino Real, Benicia and Pircinque, and the selection CE 56 performed as the most adapted to the region of study, among the genotypes evaluated.

Keywords: *Fragaria* vs. *ananassa* Duch.; selection of genotypes; yield; fruit quality.

INTRODUCTION

Strawberry production is an activity with great socioeconomic relevance in many Brazilian municipalities, constituting an important source of employment and income in small and medium-sized properties that use family labor (Fachinello *et al.*, 2011). When growing strawberries, it is necessary to optimize every aspects of the production chain in order to obtain the maximum yield possible. This is because, although it allows a high economic return even in small areas, the cost of production is also high (Ronque *et al*., 2013).

One of the most important aspects in planning a commercial cultivation of strawberries is the correct choice of cultivar, which must be adapted to conditions of the growing site (Pádua *et al*., 2015). The main environmental factors that determine the adaptability of strawberry cultivars are the photoperiod, temperature and the interaction between these factors (Sønsteby & Heide, 2017). Flowering and fructification occur only under certain temperature and photoperiod ranges. Under of temperature and / or photoperiod conditions above the limit value, plants only maintain vegetative growth and stolon emission rather than fruit production (Heide *et al*., 2013). The use of non-adapted cultivars can make the production of strawberries infeasible, even if crop management is carried out in the best possible way (Antunes *et al*., 2010).

In Brazil, national cultivars of strawberries had great importance until the 1990s. From the 2000s on, however, cultivars originating in other countries, mainly the United States and Spain, began to be used (Antunes & Peres, 2013). Under Brazilian conditions, these cultivars generally express some interesting characteristics, such as high yield and fruits with attractive external appearance. However, overly acidic taste for consumer preference, and susceptibility to various diseases and pests are problems

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commonly encountered with these cultivars (Oliveira & Bonow, 2012).

Therefore, when introducing new cultivars, it is necessary to carry out adaptability studies with them, in order to determine if these cultivars will express the desired agronomic performance (Costa *et al*., 2015). The cultivar used, in turn, interferes in all aspects of the production chain, such as planting date, fertilization, labor contracting, phytosanitary control, harvest and destination of commercialization (Oliveira & Bonow, 2012).

In this sense, the Santa Catarina State University (UDESC), in partnership with the *Consiglio per la Ricerca in Agricoltura and L 'Analisi dell' Economia Agraria - Unità di Ricerca per la Frutticoltura* (CREA-FRF), from Italy, has established an agreement for introduction and evaluation of Italian genotypes in Brazilian territory. This project aims to increase the number of cultivars available to producers, thus contributing to improvements in several aspects of the production chain.

The objective of this work was to evaluate cultivars and advanced selections of strawberry, regarding productive performance and fruit quality, under the conditions of South Plateau of Santa Catarina State.

MATERIAL AND METHODS

The experiment was conducted at the Center of Agroveterinary Sciences of the State University of Santa Catarina (CAV-UDESC), located in the municipality of Lages, in Santa Catarina State. The experimental area is located under the coordinates 27 ° 47'05 '' South latitude and 50 ° 18'08 '' West longitude, at an altitude of 906 meters. The local climate is classified as humid warm temperate (Cfb), by Köppen classification, with annual mean temperature of 15.6 °C and annual average rainfall of approximately 1,400 mm (Wrege *et al.*, 2012).

The experiment was carried out in the 2016/2017 growing season. The experimental design was in randomized blocks, with four replications, and plots of eleven plants. The treatments consisted of 16 strawberry genotypes, as follows: seven North American cultivars (Albion, Aromas, Benicia, Camarosa, Camino Real, Monterey and Portola); two Italian cultivars (Pircinque and Jonica) and seven Italian advanced selections, developed in CREA-FRF (Italy) (CE 51, CE 56, FRF 57.6, FRF 104.1, FRF LAM 269.18, FRF LAM 119.1 and FRF PA 109.2).

The experiment was installed on April 14, 2016. The cultivation system was in the open field, using beds prepared with an implement coupled in a tractor, and covered with black polyethylene film. The planting spacing used was 30 cm, between lines and plants, with three planting rows per bed. The irrigation system used was drip irrigation, with three dripping hoses per bed, provided with drippers spaced 15 cm apart.

Soil correction and basic fertilization were done four weeks prior to planting, based on recommendations in the Manual of Fertilization and Liming for the states of Rio Grande do Sul and Santa Catarina (SBCS, 2004). Coating fertilizations were carried out by weekly fertirrigation, supplying the following products: calcium nitrate [$Ca(NO_3)_2$] (99.2 g 1000 plants^{-1}); magnesium sulfate ($MgSO_4$) (45.5 g 1000 plants^{-1}); potassium sulfate (K_2SO_4) (312.5 g 1000 plants^{-1}); monoammonium phosphate (MAP) (387.4 g 1000 plants^{-1}), and P51 (liquid fertilizer containing 51% phosphorus) (73 mL 1000 plants^{-1}). Before the start of flowering, fertigations were performed with 1/4 of the doses described above. The control of weeds was carried out by means of weeding between the beds and manual tillage in the planting pits. Phytosanitary management was carried out when necessary, with recommended fungicides and insecticides for the crop.

Harvests began on September 2, 2016 and lasted until January 26, 2017, totaling 27 harvests. The fruits were picked up when they presented at least 80% of the red epidermis. After each harvest, the fruits were taken to the Food Technology Laboratory of the CAV-UDESC (NUTA 3) where the fruits were collected and weighed. This procedure was performed by discriminating the fruits according to the following criteria: a) commercial - fruits with 10g or more and free of rot or deformity; (b) small: fruit less than 10 g; c) rotten: those with symptoms of fruit rot, mainly gray mold (*Botrytis cinerea*) and anthracnose (*Colletotrichum acutatum*); and (d) misshapen: fruit misshapen in the epidermis.

At the end of the harvest period, the following production variables were estimated: a) number of fruits per plant, total and commercial (fruits plant^{-1}); b) total and commercial yield (g plant^{-1}); c) total and commercial yield (t ha^{-1}) – estimated by multiplying the yield per plant by the planting density used, which was 58,533.64 plants per hectare; d) average weight of commercial fruits (g fruit^{-1}) - calculated by dividing the commercial yield (g plant^{-1}) by the number of commercial fruits (fruits plant^{-1}), in each plot; and e) percentage of production obtained in each discrimination criterion (%) - commercial, small, rotten and misshapen - as a percentage of total yield, calculated by dividing the fruit yield obtained within each classification criterion by the total productivity, and then multiplying the results by 100.

Fruit quality was evaluated by means of two batteries of physical-chemical analyzes, carried out on October 10 and November 10, 2016. These analyzes were done at the CAV-UDESC Fruit Laboratory. The qualitative evaluations were as follows: a) firmness of pulp - obtained with the aid of a digital bench penetrometer, equipped with a pressure head with 3.5 mm diameter, in a maximum of ten fruits per plot, on both sides of each fruit. Results were provided in Newtons (N); b) titratable acidity - carried out by means of the titration of a 5 mL sample of the juice extracted from all the fruits of each plot, using a solution of sodium hydroxide (NaOH) 0.1 N, using phenolphthalein as acid-base indicator to the point of color change of the sample. The 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 juice sample on the prism of a digital refractometer. The 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.

Data were submitted to the Shapiro-Wilk normality test and Levènee variance homogeneity test, using R software (R Development Cor Team, 2013). When these conditions were met, the analysis of variance was performed and the data were grouped by the Scott-Knott test, at 5% probability of error, using the Sisvar program (Ferreira, 2011). Data of total and commercial yield (g $plant^{-1}$), average commercial fruit weight (g $fruit^{-1}$) and pulp firmness (N) were transformed by the formula $Y = x^{0,5}$. Data of total and commercial yield (t ha^{-1}), number of fruits per plant (fruits $plant^{-1}$), total soluble solids (° Brix) and RATIO were transformed by the formula Y = log x. Data of percentage of commercial and small fruits (%), in turn, were transformed by the formula $Y = \text{arc sen } (x/100)^{0,5}$; and data of percentage of misshapen and rot fruits were transformed by the formula $Y = (x+1)^{0,5}$. Estimates of Pearson correlations between the variables obtained, at 1 and 5% of significance, were performed using the software R.

RESULTS AND DISCUSSION

There was significant diference between the genotypes studied in the productive performance (Table 1). Cultivars Camino Real, Benicia and Pircinque, and the selection CE 56 had obtained the highest yields, forming a single group of averages for this variable. Highest commercial yields, in turn, were found in Camino Real and Benicia.

The cultivars Camino Real and Benicia had obtained commercial yields closest to the Brazilian average yield, which is 36.1 t ha^{-1} (Fagherazzi *et al*., 2016). However, the commercial yield of seven genotypes (Camino Real, Benicia, Pircinque, CE 56, FRF 104.1, CE 51 and FRF 57.6) exceeded or approached to the world average strawberry yield, which is 22.7 t ha^{-1} (FAO, 2018).

According to Shaw & Larson (2002), Camino Real has a yield potencial similar to the cultivar Camarosa and, when grown under favorable conditions, can produce fruits higher than 30 g. Benicia, in turn, if well managed, also has a great productive potencial and fruits with high average weight (Shaw & Larson, 2012). In the conditions of the state of California, USA, Ferreira *et al*. (2019) had obtained a mean total yield of 41.9 t ha^{-1} with the cultivar Benicia, being this yield superior to cultivar Albion, which had produced 29.6 t ha^{-1}.

In the present work, the low productivity of some cultivars and selections may be related to the non-adaptation of these genotypes to the study site. Evaluating different strawberry genotypes on yield performance during two growing seasons in three distinct environments within the Espírito Santo State, Costa *et al*. (2016) had obtained significance for the variance components genotypes and environments, as well as the interactions between these components. According to the same authors, variations in temperature, rainfall, relative humidity and incidence of diseases and pests are among the main factors responsible for the environmental variance for strawberry yield. According to Hancock *et al*. (2008), with productivity being a polygenic and quantitative characteristic, a great influence of the environment on the productive performance of strawberry cultivars is observed.

Highest averages for total and commercial number of fruits per plant (Table 2) were obtained in the genotypes CE 56, Camino Real, CE 51, Pircinque, FRF 104.1, Benicia and FRF 57.6. Benicia, Camino Real and Monterey had achieved highest values for average commercial fruit weight, being composed the group of means with the best results for this variable.

Data of number of fruits per plant found in this work were lower than those achieved by Ferreira *et al*. (2019), which obtained averages for the number of fruits per plant of 50.5, 45.4 and 31.8 for the Benicia, Monterey and Albion cultivars, respectively, and those obtained by Costa *et al*. (2018), which obtained averages of number of fruits oscillating between 24.6 and 42.67 fruits per plant, evaluating twelve cultivars, among them Albion, Aromas and Camarosa. However, the number of fruits per plant found in this work for the cultivars Camino Real and Camarosa was higher than those obtained by Araújo *et al*. (2016), which obtained averages of 15.28 fruits $plant^{-1}$ (Camino Real) and 15.77 fruits $plant^{-1}$ (Camarosa). Environmental factors, such as planting time (Ruan *et al*. 2011; Ariza *et al*., 2012), temperature and relative humidity fluctuations (Costa *et al*., 2016), type and quality of the planting material (Ruan *et al*., 2011), cultivation (Ariza *et al*., 2012; Araújo *et al*., 2016) and diseases incidence (Oliveira & Bonow, 2012) may cause these oscillations in the variable number of fruits per plant.

The commercial average mass values obtained in the present work, in turn, are in agreement with those found by Whitaker *et al*. (2011), which achieved average masses ranging from 16.2 to 30.8 g $fruit^{-1}$, as well as the results of Ruan *et al*. (2011), which obtained average commercial masses ranging from 17.7 to 19.0 g $fruit^{-1}$. The average mass of strawberry fruits is a quantitative characteristic (Hancock *et al*., 2008) and largely defined by the genetics of the cultivar (Whitaker *et al*., 2011), but that can be affected by all the environmental factors described in the previous paragraph (Ruan *et al*., 2011, Ariza *et al*., 2012, Costa *et al*., 2015, 2016).

The number of fruits per plant and the average mass of fruits are the two main components of productivity in the strawberry (Oliveira & Bonow, 2012). According to Hancock *et al*. (2008), other variables closely related to strawberry productivity are the number of crowns per cultivated area, plant vigor, number of flowers per plant,

Table 1: Productive performance of cultivars and selections of strawberry (*Fragaria* vs. *ananassa* Duch.) under conditions of South Plateau of Santa Catarina State

Genotype	Yield (g plant^{-1})**		Yield (t ha^{-1})**	
	Total	Commercial	Total	Commercial
Albion	341.26 c*	318.44 c	19.98 b	18.64 c
Camino Real	673.09 a	611.52 a	39.40 a	35.79 a
Camarosa	368.21 c	336.08 c	21.55 b	19.67 b
Pircinque	552.97 a	496.41 b	32.37 a	29.06 a
Jonica	301.98 c	274.79 c	17.68 b	16.08 c
CE 51	462.59 b	388.58 b	27.08 a	22.74 b
FRF 57.6	444.59 b	387.22 b	26.02 a	22.67 b
FRF LAM 119.1	347.15 c	289.88 c	20.32 b	16.97 c
FRF 104.1	460.47 b	397.49 b	26.95 a	23.27 b
FRF PA 109.2	297.26 c	266.91 c	17.40 b	15.62 c
FRF LAM 269.18	319.59 c	287.59 c	18.71 b	16.83 c
CE 56	545.97 a	473.65 b	31.96 a	27.72 a
Aromas	253.38 d	228.45 d	14.83 c	13.37 d
Monterey	197.62 d	174.05 d	11.57 c	10.19 d
Benicia	619.78 a	589.36 a	36.28 a	34.50 a
Portola	204.44 d	181.00 d	11.97 c	10.59 d
CV (%)	12.31	12.30	8.87	9.10

* Means followed by the same letters belong to the same group by the Scott-Knott test at 5% probability of error.

** Yield data (g plant^{-1}) transformed by the formula $Y = x^{0.5}$. Yield data (t ha^{-1}) transformed by the formula $Y = \log x$.

Table 2: Number of fruits per plant, total and commercial, and average commercial fruit weight, in cultivars and selections of strawberry

Genotype	Number of fruits (fruits plant^{-1})**		Average commercial fruit weight (g fruit^{-1})**
	Total	Commercial	
Albion	18.64 b*	15.13 b	20.74 b
Camino Real	34.00 a	25.68 a	23.81 a
Camarosa	20.41 b	16.09 b	20.92 b
Pircinque	33.12 a	23.84 a	20.81 b
Jonica	18.85 b	14.50 b	19.04 b
CE 51	32.61 a	22.27 a	17.40 c
FRF 57.6	26.21 a	19.28 a	20.02 b
FRF LAM 119.1	23.22 b	16.10 b	19.61 b
FRF 104.1	32.17 a	22.18 a	17.96 c
FRF PA 109.2	16.93 b	12.93 b	20.66 b
FRF LAM 269.18	18.93 b	15.13 b	19.19 b
CE 56	39.59 a	28.52 a	16.71 c
Aromas	15.04 c	11.68 b	19.22 b
Monterey	10.36 c	7.26 c	23.49 a
Benicia	28.30 a	23.87 a	24.66 a
Portola	13.80 c	9.30 c	19.81 b
CV (%)	9.03	9.78	4.79

* Means followed by the same letters belong to the same group by the Scott-Knott test at 5% probability of error.

** Data of average commercial fruit weight transformed by the formula $Y = x^{0,5}$. Data of number of fruits per plant transformed by the formula $Y = \log x$.

hardiness and resistance to pests and diseases. According to the same authors, these variables have, in their majority, high values of heritability, allowing high genetic gains for these characteristics through several cycles of crosses and selection of the best genotypes. As an example, Mishra *et al*. (2015) obtained heritability values of 74.81%, 85.17% and 98.44% for number of fruits per plant, average fruit mass and productivity, respectively. Singh *et al*. (2018), in turn, achieved values for genetic advance as percentage of mean of 55.56, 20.51 and 86.43% for number of fruits, average fruit weight and yield per plant, respectively.

About the percentage of total yield classified as commercial (Table 3), best results were obtained in the genotypes Benicia, Albion, Camarosa, Camino Real, Jonica, FRF PA 109.2, FRF LAM 269.18, Aromas and Pircinque. These genotypes had formed an unique group for this variable. Higher presence of commercial fruits in these genotypes can be a consequence of high average fruit weight, given that, among the not marketable fruits, small fruits were the more representative category.

The percentage of yield classified as commercial is one of the most important production parameters in the strawberry because it directly interferes in the profitability of the investment. This is because external size and appearance are among the first factors taken into account by consumers when making purchasing decisions, with consumers preferring large fruits, without defects an with intense red external coloration (Carpenedo *et al*., 2016). In addition, the exaggerated production of small fruits makes harvesting more costly and time consuming, increasing labor costs, which is one of the most relevant components of strawberry production cost (Ronque *et al*., 2013).

Higher percentages of fruits classified as small (see Table 3) were found in CE 51, FRF PA 109.2, CE 56 and Portola; and misshapen fruits, in turn, in Aromas, Jonica, FRF LAM 269.18, Monterey, FRF LAM 119.1 and Camarosa. There was no significant difference between the genotypes for percentage of rotten fruit, with a small share of this category in the total number of fruits produced.

In the selections CE 51 and CE 56, the high incidence of small fruits is a consequence of the very branched inflorescence of these selections, which, at the end of the cycle, results in the reduction of fruit size. Another possible explanation is the fact that these selections are in the group with the highest number of fruits, both total and commercial. According to Hancock *et al*. (2008), it is common number and average fruit weight to be inversely correlated in the strawberry, since the partitioning of photoassimilates into a larger number of fruits reduces their average size. The presence of misshapen fruits, in turn, may be a characteristic linked to the genetic load of the cultivar and some environmental factors, as described by Ariza *et al*. (2012). According to these authors, the incidence of misshapen fruits in the strawberry is a consequence of pollination failures, which can occurs due to several factors, such as cultivar, planting season, average temperature and presence of pollinators.

The planting season exerts influence on the temperature and humidity conditions that the plants receive, which, in turn, interferes with the efficiency of pollination. Franquez (2008) states that very low temperatures and excessive humidity reduce the viability of the pollen grains, leading to losses on the fertilization of the achenes. The pollinator insects, together with the wind, in turn, are the main agents of pollination in the strawberry (Malagodi-Braga & Kleinert, 2007).

Regarding the qualitative characteristics, only for the variable pulp firmness was not observed difference between the genotypes (Table 4). For the titratable acidity three groups of averages were formed. Albion, Camarosa, Jonica and FRF LAM 269.18 composed the group with the highest values of acidity. For the soluble solids content (°Brix) two groups of means were formed, the group with the highest means being composed by the selections CE 56, FRF LAM 269.18, CE 51, FRF 104.1, FRF PA 109.2, FRF 57.6 and FRF LAM 119.1, and by the cultivars Benicia, Camino Real and Albion. For the variable soluble solids / titratable acidity ratio, three groups of means were formed, the best group being formed by the selections FRF 104.1, FRF PA 109.2, FRF 57.6, CE 56, FRF LAM 119.1 and CE 51, and by the cultivars Benicia and Monterey.

The fact that there was no difference between the genotypes studied for pulp firmness was contrary to the expected one, considering that there is a wide variability between different populations of strawberry for this characteristic (Hancock *et al*., 2008) and it is subject to high selection gain in breeding programs, and may reach more than 50% gain per selection (Murti *et al*., 2012).

For the titratable acidity variable, no different results were observed according to the origin of the evaluated accessions. Both Italian and American genotypes were present in the groups of averages with higher and lower acidity values. Similar fact occurred for the soluble solids content. Among the accessions with higher sugar contents, there was a marked presence of the Italian advanced selections, and all the selections were present in the first group of means for this variable. However, in this group were also allocated the American cultivars Albion, Camino Real and Benicia. These cultivars often obtain a higher concentration of soluble solids in comparison with other cultivars developed at the University of California between the decades of 1990 and 2000 (Shaw & Larson, 2002; 2006; 2012).

The American cultivars Monterey and Benicia, together with the Italian selections, made up the group with the highest values of SS/TA ratio. The exception among the Italian selections was FRF LAM 269.18, which was not part of this group because it obtained one of the highest averages of acidity. The genotypes group with the lowest SS/TA ratio was composed by the American cultivars Albion, Camarosa and Portola. With Albion, this occurred because the fruits of this cultivar obtained high acidity. In the cultivar Portola, in

Table 3: Fruit production in different categories, as a percentage of total yield, in cultivars and selections of strawberry

Genotype	Percentage of fruits in different categories (%)**			
	Commercial	**Small**	**Misshapen**	**Rotten**
Albion	92.91 a*	4.83 b	0.71 b	1.55 a
Camino Real	90.98 a	7.65 b	0.30 b	1.07 a
Camarosa	91.17 a	5.74 b	1.18 a	1.91 a
Pircinque	89.66 a	8.84 b	0.38 b	1.12 a
Jonica	91.03 a	5.99 b	1.74 a	1.23 a
CE 51	83.67 b	14.01 a	0.06 b	2.26 a
FRF 57.6	86.55 b	8.03 b	0.65 b	4.77 a
FRF LAM 119.1	85.89 b	8.34 b	1.23 a	4.54 a
FRF 104.1	86.22 b	12.71 a	1.12 b	0.94 a
FRF PA 109.2	90.53 a	7.54 b	0.39 b	1.54 a
FRF LAM 269.18	90.08 a	5.66 b	1.60 a	2.66 a
CE 56	86.57 b	12.11 a	0.13 b	1.19 a
Aromas	90.03 a	7.02 b	2.14 a	0.81 a
Monterey	87.87 b	7.77 b	1.37 a	2.98 a
Benicia	95.05 a	3.56 b	0.17 b	1.22 a
Portola	88.63 b	11.16 a	0.22 b	0.00 a
CV (%)	4.70	18.39	25.58	33.38

* Means followed by same letters belong to the same group by the Scott-Knott test at 5% probability of error.

** Data of percentage of commercial and small fruits transformed by the formula $Y = \text{arc sen } (x/100)^{0,5}$; and data of percentage of misshapen and rotten fruits transformed by the formula $Y = (x+1)^{0,5}$.

Table 4: Fruit quality traits in cultivars and selections of strawberry, under conditions of South Plateau of Santa Catarina State

Genotype	Pulp firmness (N)**	Titratable acidity (g 100 g^{-1} of citric acid)	Soluble solids (°Brix)**	Soluble solids / titratable acidity ratio**
Albion	5.50 a*	0.73 a	8.53 a	11.55 c
Camino Real	5.59 a	0.67 b	8.67 a	12.90 b
Camarosa	5.45 a	0.72 a	7.73 b	10.79 c
Pircinque	5.52 a	0.58 c	7.50 b	12.96 b
Jonica	5.57 a	0.71 a	8.18 b	12.19 b
CE 51	5.62 a	0.65 b	9.03 a	13.81 a
FRF 57.6	5.20 a	0.58 c	8.75 a	15.08 a
FRF LAM 119.1	5.07 a	0.61 c	8.73 a	14.30 a
FRF 104.1	5.67 a	0.55 c	8.88 a	16.20 a
FRF PA 109.2	5.62 a	0.56 c	8.77 a	15.75 a
FRF LAM 269.18	5.67 a	0.73 a	9.37 a	12.76 b
CE 56	5.72 a	0.64 b	9.50 a	14.74 a
Aromas	5.54 a	0.63 c	7.95 b	12.58 b
Monterey	5.31 a	0.57 c	8.00 b	14.08 a
Benicia	5.54 a	0.60 c	8.97 a	15.05 a
Portola	5.70 a	0.69 b	7.63 b	11.16 c
CV (%)	2.72	6.16	4.20	3.83

* Means followed by the same letters belong to the same group by the Scott-Knott test at 5% probability of error.

** Pulp firmness data transformed by the formula $Y = x^{0,5}$; data of total soluble solids and soluble solids / titratable acidity ratio transformed by the formula Y = log x.

turn, this relation was one of the smaller ones, due to the low content of soluble solids in relation to the majority of the genotypes. For Camarosa cultivar, this occurred both because it had high acidity and one of the lowest soluble solids content.

The pulp acidity of strawberry fruits is provided by organic acids, among which citric acid is the main. The soluble solids content is composed by some polysaccharides, among which glucose, sucrose and fructose are present in higher concentrations (Hancock *et al*., 2008). According to the same authors, strawberry acidity and soluble solids content are traits inherited quantitatively, controlled by several genes, with variable degrees of additive and dominant control. Mishra *et al*. (2015) found heritability in the broad sense values of 85.42 and 93.73% for titratable acidity and soluble solids content, respectively, attesting that the correct selection of the most promising genotypes can lead to significant gains for these traits in breeding programs.

Strawberry fruits with high soluble solids / titratable acidity ratio are more likely to be chosen by consumers (Carpenedo *et al*., 2016), with high acidity being an unfavorable factor in this sense (Resende *et al*., 2008). The fruits of the Italian genotypes are markedly sweet, as this is one of the most sought after characteristics by strawberry breeding programs in that country (Fagherazzi, 2017).

According to Kader (2002) cited by Souza *et al.* (2017) the quality parameters considered suitable for commercialization of strawberries as fresh fruit are as follows: maximum of 0.80 g $100g^{-1}$ of citric acid for titratable acidity; minimum of 7.0 ° Brix for soluble solids content; and minimum of 8.75 for SS/TA ratio. Thus, all the genotypes evaluated in this work presented parameters of fruit quality that make them suitable for *in natura* commercialization.

Estimates of Pearson correlations between the variables obtained are presented in Table 5. Total and commercial yield were strongly correlated to number of fruits per plant, with magnitudes between 0.85 and 0.94, but were not significatively correlated to average fruit weight. This result is in agreement with the one obtained by Fagherazzi (2017), for which the number of fruits per plant correlated strongly with yield, while the average commercial fruit weight did not significantly influence the total production. For Mishra *et al*. (2015), in contrast, productivity was more strongly correlated with fresh fruit weight than number of fruits, although both correlations were significant. Singh *et al*. (2018), in turn, have found positive correlation between yield and both number of fruits per plant and average fruit weight. These authors have also obtained positive correlation between yield and fruit breadth. In the present study, however, it is worth noting that the cultivars Camino Real and Benicia, which obtained the highest commercial yields, also stood out for the average fruit mass (Tables 1 and 2).

In the present work, the average commercial fruit weight interfered positively in the percentage of fruits classified as commercial, considering that, withing the non-marketable fruits, the most representative portion was the small fruits (see Table 3). Probably, this is also the reason for the inverse correlation between the variables percentage of the yield classified as commercial and number of fruits per plant. Fagherazzi (2017) also obtained an inverse correlation between these variables. However, Mishra *et al.* (2015) found a strong and positive correlation between number of fruits per plant and average fresh weight, suggesting that this relation can change depending of the population studied.

Pulp firmness did not correlate significantly with any other variables. This disagrees with the results found by Murti *et al*. (2012), for which pulp firmness was significantly correlated with color of the epidermis and soluble solids content of the fruits.

There was a positive correlation between soluble solids content and the variables total and commercial number of fruits per plant, and total yield. This positive correlation contradicts some information present in the literature. In strawberry, in the majority of cases, yield is inversely related to the sugar content in fruits (Hancock *et al*., 2008). However, Mishra *et al*. (2015) obtained a strongly positive correlation between yield and total sugars, while Singh *et al*. (2018) have found a weak inverse correlation for these variables.

In the present study, the genotypes Benicia and CE 56 obtained a positive result, simultaneously, for yield and soluble solids / titratable acidity ratio (Tables 1 and 4). The cultivar Camino Real, in turn, was part of the groups with the highest averages, at the same time, for production and soluble solids content. Thus, the result of this work may be an indication that the simultaneous selection of genotypes combining high yield and fruits with high soluble solids content, although challenging, is possible.

The most economically important characteristics for strawberry crop, such as fruit size and soluble solids content are, for the most part, highly variable among genotypes and influenced by the environment (Ghoochani *et al*., 2015). Thus, the correlation analysis is an important tool for correct selection of the most promising genotypes (Singh *et al*, 2018). Estimates of correlations between variables provide strategic information for strawberry breeding or adaptability studies, in which yield and fruit quality are usually sought simultaneously (Mishra *et al*., 2015).

Table 5: Pearson's correlations matrix between variables obtained in an adaptability study with cultivars and selections of strawberry

	TY	CY	AW	PC	NC	TN	PF	TA	SS	RT
TY	-	0.99*	0.16	0.02	0.94**	0.90**	0.07	-0.10	0.25**	0.23
CY		-	0.23	0.14	0.92**	0.85**	0.07	-0.07	0.23	0.19
AW			-	0.48**	0.14	-0.23	-0.07	-0.11	-0.18	-0.07
PC				-	-0.07	-0.26*	-0.04	0.23	-0.13	-0.28*
NC					-	0.97**	0.07	-0.08	0.29**	0.25*
TN						-	0.07	-0.13	0.28*	0.28*
PF							-	0.07	0.07	0.00
TA								-	0.09	-0.71**
SS									-	0.63**
RT										-

* Significant correlation at 5% probability of error.

** Significant correlation at 1% probability of error.

TY: total yield; CY: commercial yield; AW: average commercial fruit weight; PC: percentage of yield classified as commercial; NC: number of commercial fruits; TN: total number of fruits; PF: pulp firmness; TA: titratable acidity; SS: soluble solids content; RT: soluble solids / titratable acidity ratio.

CONCLUSIONS

The cultivars Camino Real, Benicia and Pircinque, and the selection CE 56 obtained the highest yields. These genotypes performed as the most adapted to the region of study, among the genotypes evaluated.

Yield was positively correlated with the number of fruits per plant and the soluble solids content.

The selections FRF 104.1, FRF PA 109.2, FRF 57.6, CE 56, FRF LAM 119.1 and CE 51, and the cultivars Benicia and Monterey stood out for the good quality of fruits, expressed by high soluble solids / titratable acidity ratio averages.

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