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Culture systems in the production and quality of strawberry cultivars

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ABSTRACT. Until recently, strawberry cultivation was exclusively performed in soil using conventional cultivation methods, which resulted in many environmental and phytosanitary problems. Currently, soilless culture is the production method advocated for environmental reasons because it greatly reduces the use of chemical pesticide and fungicide inputs. This study assessed the yield and quality of fruits from strawberry cultivars grown in two systems (soil and substrate) in a greenhouse. The experiment was performed from September 2010 to January 2011 in the University of Passo Fundo, Rio Grande do Sul State. Treatments (cultivars x culture systems) were arranged in a random block design with a 7 x 2 factorial arrangement. Evaluation included number, total and commercial fresh weight of fruits per plant, transversal diameter, total titratable acidity (TTA), total soluble solids (TSS), TSS/TTA ratio and the pH of fruits. The cultivars Camarosa, Florida Festival and Portola excelled in relation to yield when grown in the soil system. In substrate culture, all cultivars had similar performance. The yield was higher in soil culture, while the quality was higher in the substrate system.

Keywords: *Fragaria X ananassa* Duch., soil culture, substrate culture.

Sistemas de cultivo na produção e qualidade de cultivares de morangueiro

RESUMO. Até alguns anos atrás o cultivo do morangueiro era realizado somente no solo, da forma convencional de cultivo, o que gerava muitos problemas ambientais e fitossanitários. Atualmente, o sistema de cultivo sem solo é o método de produção que vem sendo sustentado pelas questões ambientais, diminuindo muito a utilização de defensivos e insumos. O objetivo do trabalho foi verificar a produção e a qualidade dos frutos de cultivares de morangueiro, produzidos em dois sistemas (solo e substrato), em ambiente protegido. O experimento foi realizado no período de setembro de 2010 a janeiro de 2011, na Universidade de Passo Fundo, Rio Grande do Sul. Os tratamentos (cultivares x sistemas de cultivo) foram dispostos no delineamento em blocos casualizados, com arranjo fatorial 7 x 2. As avaliações constaram do número e massa fresca total e comercial de frutos por planta, diâmetro transversal, acidez total titulável (ATT), sólidos solúveis totais (SST), ratio SST/ATT e pH dos frutos. Destacaram-se pelo rendimento as cultivares Camarosa, Florida Festival e Portola, quando produzidas no solo. No cultivo em substrato todas as cultivares apresentam o mesmo desempenho. O rendimento foi maior no cultivo em solo, porém a qualidade foi superior no sistema de produção em substrato.

Palavras-chave: *Fragaria X ananassa* Duch., cultivo em solo, cultivo em substrato.

Introduction

Strawberry culture is highly important for economic and social reasons, mainly for aggregating family labor, as cultivation on small rural properties is predominant (PONCE et al., 2010). Properties in the states of Minas Gerais, Rio Grande do Sul and São Paulo enjoy nationwide prominence, where nearly all of the production is derived from soil culture (RADIN et al., 2011).

One of the problems related to conventional strawberry cultivation is the excessive use of pesticides. In the predominant strawberry cultivation system, high loads of pesticides are employed, making it among the four crops with the highest rates of pesticide contamination. Several solutions have been proposed for the minimization of these problems, among which greenhouse cultivation stands out because in addition to protecting the crop from wind, hail, rain, frost and low temperatures, it also reduces the prevalence of pests and diseases, providing better conditions for plant development and improving total fructification and commercial production (ANTUNES et al., 2007; CALVETE et al., 2008). However, strawberry culture in the greenhouse environment, which uses primarily soil, has productivity issues due to the susceptibility of this crop to damage by soil fungi

and bacterioses. The phytosanitary limitations of soil motivated the development and use of soilless culture techniques, including hydroponics.

Hydroponic production has been used for thousands of years where suitable soil is unavailable for growth or where the soil is contaminated (JAFARNIA et al., 2010). Until 2004, this type of system occupied an area of approximately 1,140 ha in Europe (LIETEN et al., 2004), but these cultivation systems are expanding around the world.

Soilless strawberry culture using greenhouses extends the crop period, allows out of season production and increases the yield (JAFARNIA et al., 2010). This system has many other advantages as it enables the removal of disinfection products as well as reduces pesticide use, decreases the consumption of contaminated fruits and decreases environmental harm while increasing fruit quality and allowing greater ability to manage cultivation (CALVETE et al., 2007).

In the last few decades, agronomic research has prioritized the attainment of high productivity, improved resistance to diseases and pests, transportability and extended shelf life of the fruit. Moreover, programs are improving the types and quality of fruits (in term of sensory and nutritional aspects) and the production systems (CAPOCASA et al., 2008).

This study provides an evaluation of the yield and quality of fruits from different strawberry cultivars produced in a greenhouse using soil and substrate media.

Material and methods

The experiment was performed from May 12, 2010 to January 19, 2011 in the greenhouse of the Horticulture Sector of the School of Agronomy and Veterinary Science of the University of Passo Fundo, Rio Grande do Sul State, Brazil, situated at 28º15'41" S, 52º24'45" W with an altitude of 709 m.

The research was conducted in a 3.5 m high agricultural greenhouse with a semicircular roof and 510 m^2 of covered area (51 m long x 10 m wide), oriented in a northeast-southeast direction. The structure was constructed of galvanized steel and covered with a 150 micron thick low-density polyethylene (LDPE) diffused film with an anti-ultraviolet additive. A wire screen was attached to the greenhouse sides, along with mobile curtains, to prevent the entry of persons and birds while allowing access for pollinating insects.

The treatments consisted of 7 strawberry cultivars and 2 growing systems (soil and substrate media). The cultivars assessed were as follows: Camarosa, Florida Festival, Camino Real, San Andreas, Monterey, Portola and Ventana. The treatments were arranged in a randomized block design (RBD) using a 7 x 2 factorial arrangement with 3 repetitions and 10 plants per parcel; six plants per parcel was considered serviceable.

Seedlings were transplanted during the end of May 2010. In the substrate system, seedlings planted in a 30 x 30 cm spacing arrangement were grown in 150 micron white LDPE (with an anti-UV additive) filled with Tecnomax® commercial substrate; two plantation lines were used per 1.5 m x 0.79 m bag. In the soil system, seedlings were transplanted into 0.8 x 16 m beds covered with 30-micron-thick black LDPE mulch in the same plant arrangement as the substrate system.

Drip irrigation was used in both systems. In the substrate system, a single hose with 30 cm drippers (securely attached and located inside each bag) was installed using the same spacing between the plants. In the soil system, two hoses were placed beside each cultivation line, with drippers (spaced every 30 cm) positioned under the mulching. Fertigation in both cases was performed according to the formula described by Calvete et al. (2007).

Fruit was gathered monthly from September 2010 to January 2011. The maturation point used was the commercial standard (i.e., with 75% of the skin presenting a red color).

Post-harvest evaluations assessed the following parameters: yield determined by the total number and fresh weight of both fruits per plant and commercial fruits per plant, diameter of fruits, total titratable acidity (TTA), total soluble solids (TSS), TSS/TTA ratio, pH and external color. Fruits without injuries, diseases and deformities weighing more than 6 g were considered commercial (ANTUNES et al., 2007). The transversal diameter of fruits was determined using a digital pachymeter, and the result was expressed in millimeters (mm). Total titratable acidity (TTA), expressed in citric acid percentage, was determined by titrating 10 mL of juice in 100 mL distilled water with 0.1 N NaOH solution to pH 8.1. Brix degree (°Brix), as a measure of total soluble solids (TSS), was determined through refractometry. The TSS/TTA ratio was obtained through the coefficient between the two constituents; pH was obtained through juice analysis using a potentiometer (peagameter). External color was determined by taking a diffuse reflectance spectrophotometer reading (Hunter Lab) using a sphere geometry optical sensor; data correspond to the L★, a★ and b★ analytical components (as described by Ferreira, 1981), where L★ values (luminosity) vary from light to dark, with 100

corresponding to white and 0 (zero) corresponding to black. These values were then used to calculate degrees of hue angle (H° = arctan [b*/a*]) and chroma (C* = [a*2 + b*2]½). H° is an angle in the color wheel where 0° = red-purple, 90° = yellow, 180° = green-blue and 270° = blue. Chroma indicates intensity or saturation of color. All the evaluations were performed using 5 fruits from each parcel to determine the mean in variance analysis.

The results of the evaluations were assessed through variance analysis (with significant differences between means compared using the tukey test at 5% of error probability), and regression analysis using the CoStat statistical program (COHORT SOFTWARE, 2003).

Results and discussion

The results indicate differences between cultivars and the growing media system used, as well as the number of fruits and fresh weight (Table 1). Only the San Andreas and Monterey cultivars were similar in both systems for total and commercial fresh weight. According to Gruda (2009), the use of soilless culture technology does not imply an automatic increase in the production and quality of greens.

The cultivars Camarosa, Florida Festival and Portola grown in the soil system yielded a higher fresh weight than in the substrate medium. However, there was a general trend of a reduction in the number of fruits and fresh weight, both total and commercial, in the substrate culture.

Total fresh weight in the soil culture system was 877.51 g plant^{-1} for cv. Camarosa and 771.09 g plant^{-1} for cv. Florida Festival (Table 1), which was higher than those obtained by Antunes et al. (2010); this was also the case in the number of fruits per plant. The yields in the present study for cv. Camarosa grown in soil were also greater than those of Vignolo et al. (2011), Oliveira et al. (2008) and Watthier et al. (2011), with their recorded yields of 43.6 fruits and 813.2 g plant^{-1}, 55 fruits and 1,038 g plant^{-1} and 37.1 fruits and 600.1 g plant^{-1}, respectively. The results of this study for cv. Portola grown in soil were also higher than the 38 fruits and 600.1 g plant^{-1} recorded by Watthier et al. (2011). Only the values found by Oliveira et al. (2008) for Camino Real (44 fruits and 1,121 g plant^{-1}) were higher than the yield obtained in this study for this cultivar.

In contrast, for the substrate culture system, despite not presenting differences between the cultivars studied in relation to the number of fruits and fresh weight (both total and commercial), cv. Camarosa obtained higher fresh weight values (225 g plant^{-1}) than Radin et al. (2011) in Caxias do Sul, Rio Grande do Sul State. Caruso et al. (2011), studying *Fragaria vesca* L. in NFT system during two production cycles (summer-spring and autumn-spring), obtained a mean production of 185.2 g plant^{-1} during the cycle summer-spring and 128.2 g plant^{-1} during autumn-spring; values that were considerably lower to those obtained in the present study, where production occurred during the spring-summer cycle.

The yield performance of cultivars in relation to the total fresh weight of fruits produced during the production cycle is shown in Figure 1.

Table 1. Fruit production of 7 strawberry cultivars produced in 2 culture systems - Passo Fundo, Rio Grande do Sul State, cycle 2010/2011.

	Number of fruits per plant					
	Total			Commercial		
Cultivars	Soil	Substrate	Mean	Soil	Substrate	Mean
Camarosa	A 100 a	B 34 a	67	A 81 a	B 22 a	52
Florida Festival	A 105 a	B 37 a	71	A 91 a	B 29 a	60
San Andreas	A 31 b	A 23 a	27	A 26 b	A 18 a	22
Portola	A 55 b	B 29 a	42	A 46 b	A 23 a	3
Monterey	A 32 b	A 16 a	24	A 26 b	A 14 a	20
Ventana	A 33 b	A 23 a	28	A 29 b	A 19 a	24
Camino Real	A 30 b	A 28 a	29	A 25 b	A 24 a	25
Mean	55	27	41	46	21	34
CV (%)	18.38	27.91	55.75	18.59	30.87	60.7
			Fresh Weight (g plant^{-1})			
Camarosa	A 1.437 a	B 322 a	880	A 1.203 a	B 245 a	724
Florida Festival	A 1.430 a	B 403 a	917	A 1.292 a	B 350 a	821
San Andreas	A 498 c	A 301 a	400	A 434 c	A 266 a	350
Portola	A 1.009 ab	B 355 a	682	A 906 ab	B 310 a	608
Monterey	A 542 bc	A 218 a	380	A 463 c	A 205 a	334
Ventana	A 632 bc	B 308 a	470	A 592 bc	B 280 a	435
Camino Real	A 565 bc	B 375 a	470	A 493 bc	B 346 a	419
Mean	873	326	599	769	286	527
CV (%)	19.75	29.46	65.27	19.71	29.12	65.83

Means followed by letters in lower case in the column and preceded by the same letter capitalized in the line do not differ by Tukey test at 5% of error probability.

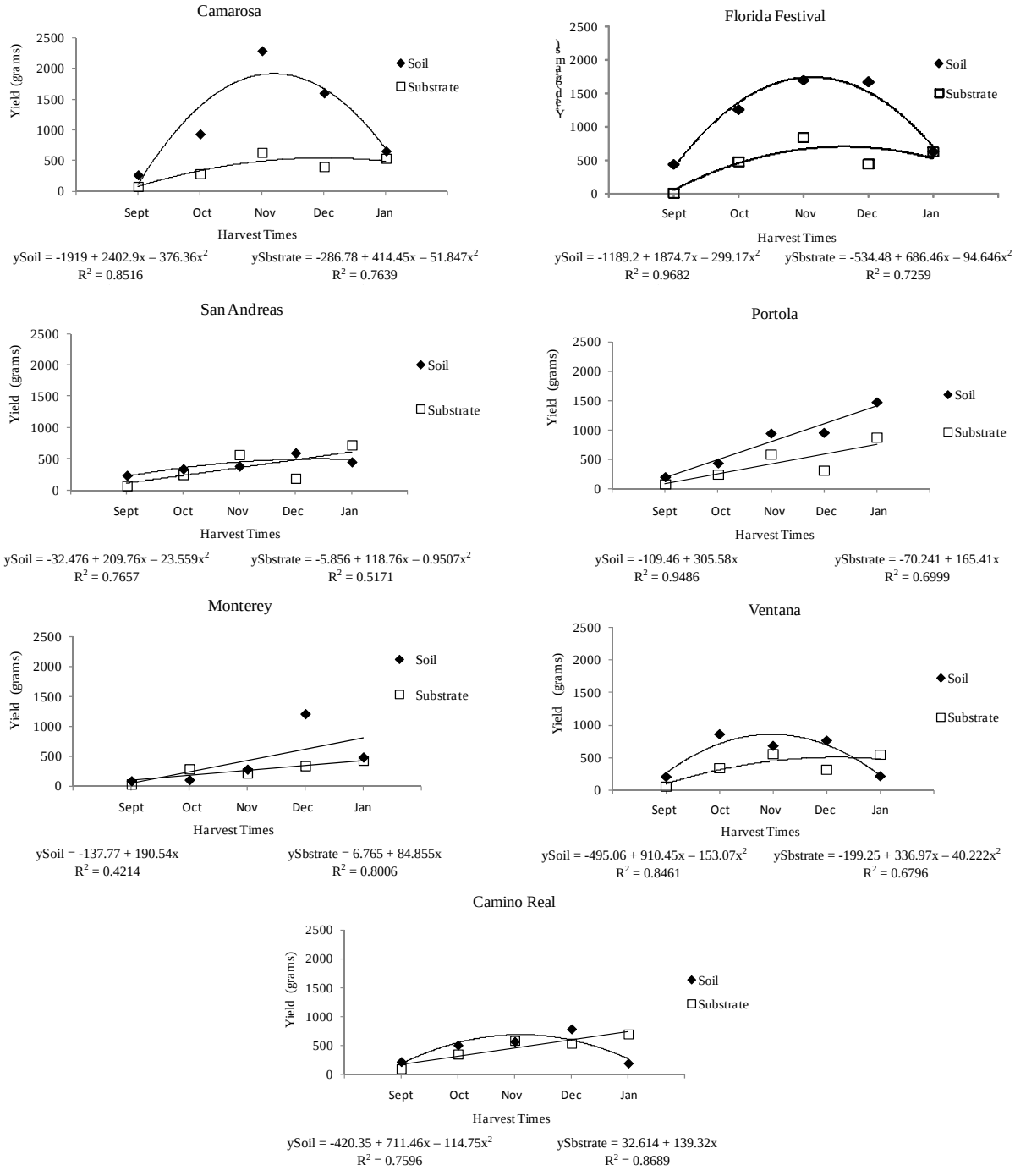

Figure 1. Yield performance during the 2010-2011 crop of 7 strawberry cultivars grown in soil and substrate, Passo Fundo, Rio Grande do Sul State, cycle 2010-2011.

Monthly yields for cultivars Camarosa, Florida Festival and Ventana resulted in a quadratic behavior for both media systems. San Andreas and Camino Real exhibited this trend only when cultivated in soil. In these two cultivars, the production peak occurred later when grown in substrate than when grown in the soil system. Using the regression equation $-b\ 2c^{-1}$, cv. Camarosa and Ventana were observed to have a one-month delay in crop peak when grown in the substrate system. Cv. Florida Festival, on the other hand, had a 15-day delay.

For both the soil and substrate systems, the peak production period for cvs. Camarosa and Florida Festival was in November (Figure 1). San Andreas, Monterey and Camino Real, when cultivated in soil, had their peak in December. In contrast, cv. San

Andreas grown in the substrate system; Portola grown in either system and Monterey, Ventana and Camino Real grown in substrate, had their production peak in January. Only Ventana, when cultivated in the soil system, had its' production peak in October. Cvs. San Andreas and Camino Real, when grown in the substrate system, and Portola and Monterey, in either of the systems, presented an upper linear growth.

Results observed for short-day strawberry cultivars confirm findings in the literature, which note that as temperature and photoperiod increase, fruit production decreases while the development of stolons increase (BRANZANTI, 1989). Neutral-day cultivars provide greater production during the hotter periods of the year than short-day cultivars because they are less sensitive to the stimulation exerted by photoperiod and temperature for the emergence of stolons and, consequently, delay their fructification period (STRASSBURGER et al., 2010). This knowledge concerning cultivar traits is important for managing their culture as this information is beneficial to producers for staggering strawberry production.

In spite of the substrate system having displayed lower production than the soil system, this medium can increase a plants' density and correspondingly, productivity, which according to Gimenez et al. (2008) is one of the advantages of the soilless system along with eliminating the ergonomic difficulties in cultivating plants in the soil, which has hindered the recruitment of labor (GODOI et al., 2009).

The quality of the fruits is highly important because, in addition to presenting an excellent appearance, they must meet the consumers' demands in relation to flavor, sweetness, acidity and color. From the post-harvest quality parameters assessed, the pH did not present any significant differences, with a mean of 2.83 (Table 2).

Table 2. Total soluble solids (TSS) and pH in strawberry fruits produced in soil and substrate, Passo Fundo, Rio Grande do Sul State, cycle 2010/2011.

Cultivar	TSS (°Brix)	pH
Camarosa	6.90 ab	3.11^{ns}
Florida Festival	7.48 a	3.1
San Andreas	6.23 abc	2.68
Monterey	5.70 bc	2.75
Portola	5.91 bc	2.73
Ventana	6.4 abc	2.99
Camino Real	5.43 c	2.44
Mean	6.29	2.83
CV (%)	13.69	12.12
Culture System		
Soil	5.76 b	2.73^{ns}
Substrate	6.81 a	2.93
Mean	6.29	2.83
CV (%)	13.92	13.36

Means followed by the same letter in lower case in the columns do not differ by the tukey test at 5% of error probability. ^{ns} – Not significant for variance analysis.

Cekic and Yilmaz (2011) evaluation of cvs. Camarosa and Maraline in soilless culture inoculated with 2 arbuscular mycorrhizal fungi and 3 doses of phosphor, obtained a mean pH of 3.87 and 3.9, respectively. These values are somewhat higher than those found in the present study and the 3.5 pH obtained by Calvete et al. (2010) for cv. Camarosa when grown in a greenhouse using the bee species *Apis mellifera* as the pollinator.

The pH measure is very important both microbiologically and chemically because most chemical reactions occurring during the processing and storing phases (i.e., during the post-harvest stage) are profoundly altered by the variation in the environment's hydrogen concentration (GOMES; OLIVEIRA, 2011). According to Figueiredo et al. (2010) the pH reduction is not due to an increase in the citric acid content, but likely to the elevation of other acids which reduce the pH and increase the pulp's acidity.

The variable, total soluble solids, differed among the cultivars and culture systems (Table 2). Fruit from cv. Florida Festival produced the highest sugar content, whereas Camino Real, Monterey and Portola had the lowest values.

TSS values in this study were lower compared to those found by other authors in the growing conditions of Rio Grande do Sul State. Malgarim et al. (2006), in Pelotas, had 7.35 °Brix for Camarosa. However, Cekic and Yilmaz (2011) had 13.31 and 14.10% for Camarosa and Maraline, respectively, much higher than the values obtained in this study using substrate culture. Brackmann et al. (2011), assessing the quality of strawberry cultivars and clones grown in soil, had a mean 7.12 °Brix, which was also higher than the results in this study. In relation to the culture system used, the greatest sugar content was found in fruits produced in substrate (6.81 °Brix).

According to Chitarra and Chitarra (2005), total soluble solids levels vary according to species, cultivar, maturation stage and climate, with a 2-25% interval and mean values of 8-14%. Soluble solids content indicates the quantity of sugar present in the fruit, considering that acids, vitamins, amino acids and pectins are also constituent parts (albeit in a smaller proportion), in the composition of a fruit's soluble solids. However, this attribute along with the acidity, is controlled by variable levels of additive and dominant variance, i.e., they are parameters that depend on heredity (BRACKMANN et al., 2011).

In relation to a fruit's diameter, titratable total acidity and TSS/TTA ratio, an interaction between cultivars and culture systems was observed (Table 3).

It was observed that the type of media system influenced the fruit diameter of the cultivars evaluated in this study.

Table 3. Diameter (mm), total titratable acidity (TTA) and TSS/TTA ratio of the fruits in strawberry cultivars produced in 2 culture systems in greenhouse, Passo Fundo, Rio Grande do Sul State, cycle 2010-2011.

	Diameter	
Cultivar	Soil	Substrate
Camarosa	A 31.2 a	A 28.22 a
Florida Festival	A 28.64 ab	A 26.81 a
San Andreas	A 25.03 ab	A 30.73 a
Monterey	A 19.75 b	A 30.48 a
Portola	A 27.72 ab	A 28.74 a
Ventana	A 27.26 ab	A 29.30 a
Camino Real	A 23.42 ab	A 24.78 a
Mean	26.14	28.44
CV (%)	9.08	5.7
	TTA	
Cultivar	Soil	Substrate
Camarosa	A 0.81 ab	A 0.95 a
Florida Festival	A 0.72 bc	A 0.73 b
San Andreas	A 1.00 a	A 0.76 ab
Monterey	B 0.48 d	A 0.72 b
Portola	A 0.62 bcd	A 0.61 b
Ventana	A 0.69 bcd	A 0.69 b
Camino Real	A 0.52 cd	A 0.66 b
Mean	0.69	0.73
CV (%)	7.56	6.5
	Ratio (TSS/TTA)	
Cultivar	Soil	Substrate
Camarosa	A 8.19 ab	A 8.97 a
Florida Festival	A 10.77 a	A 10.07 a
San Andreas	A 5.26 b	A 9.16 a
Monterey	B 5.91 b	A 9.34 a
Portola	B 6.70 b	A 11.09 a
Ventana	A 8.08 ab	A 10.26 a
Camino Real	A 6.60 b	A 8.37 a
Mean	7.6	9.61
CV (%)	12.52	10.46

Means followed by the same letter in lower case in the column and preceded by the same letter capitalized in the line do not differ by the tukey test at 5% of error probability.

However, in both systems, the fruits were considered Class I (> 25 mm), according to the Mercosul Technical Regulation Identity and Quality for Strawberry n. 85/96. Among cultivars evaluated for this parameter, cv. Camarosa grown in soil was the only one to produce larger fruits than cv. Monterey. In contrast, both cultivars had similar size fruit when grown in substrate.

The size of the fruit depends on the interaction between flower position, the number of achenes developed, competition between fruits and the plant's vigor. In addition, larger fruits are produced during the beginning of the harvest period. Branzanti (1989) perceived a reduction in the size of fruits derived from primary flowers to those developed from secondary and tertiary flowers.

In relation to the variable total titratable acidity (Table 3), only cv. Monterey was observed to have a higher increase in TTA in substrate culture than when grown in soil. When grown in soil, cv. San Andreas had a higher concentration of citric acid and cv. Monterey had lower concentrations than the other cultivars. Cv. Camarosa grown in the substrate system had a higher citric acid content in relation to the other cultivars, which may indicate a higher concentration of other acids such as ascorbic acid.

Malgarim et al. (2006), evaluating the quality of Camarosa strawberries subjected to a modified atmosphere and resveratrol during different storage periods, had 0.60% citric acid content at harvest. Zaicovski et al. (2006) had 0.66% citric acid for cv. Camarosa subjected to different treatments with resveratrol. Both studies had lower contents than that obtained in this study for cv. Camarosa. Antunes et al. (2010), evaluating the quality of cv. Florida Festival fruits grown in soil, found a similar value to that of the present study (0.74% citric acid), but for cv. Camarosa, the content found by the authors was lower (0.76% citric acid) than that observed in this study. Brackmann et al. (2011) had a mean 0.76% citric acid content, similar to that obtained for substrate culture in this study, but higher than the soil system. Cekic and Yilmaz (2011) had 0.95% citric acid for Camarosa, the same value found in this study for soil culture.

Except for Portola and Camino Real grown in a soil culture, the citric acid contents of the other cultivars corroborate Atkinson et al. (2006) who noted that the concentration of this acid in strawberry fruits varies between 0.64-1.15%.

The relation between sugar and acidity is an important parameter in determining the fruits' maturation. With respect to this parameter, only fruits from cvs. Monterey and Portola were different when produced in soil and substrate systems; those produced in substrate had a pronouncedly sweeter flavor than an acidic sensation. In soil culture, cv. Florida Festival stood out, followed by Camarosa and Ventana (Table 3). The TSS/TTA ratio noted by Antunes et al. (2010) for cv. Florida Festival (10.83) grown in soil was similar to that found in this study. However, cv. Camarosa (9.94) had a higher ratio. The same held true in comparison to the study by Malgarim et al. (2006), which obtained a 12.25 ratio for Camarosa. Brackmann et al. (2011) found fruits with a mean 9.78 ratio, a value close to that found when a substrate system is used. Resende et al. (2008), linking the relationship of TSS/TTA with consumer acceptance, found that the highest TSS/TTA ratios were associated with a better perception of the fruit's flavor and are preferred by consumers. These authors recorded a value of 13.50 for the cultivar Camp-Dover. Thus, in this study, Florida Festival would have a greater consumer acceptance than the other cultivars.

In relation to the fruits' external color, the culture system used did not appear to have an influence;

additionally, differences were not observed between cultivars in any of the variables analyzed (L*, c* and °Hue). Regardless of the cultivar and the culture system, the fruits presented a dark external color, i.e., low luminosity (L* < 29.24) and less chromatics (c* > 36.08) (Figure 2).

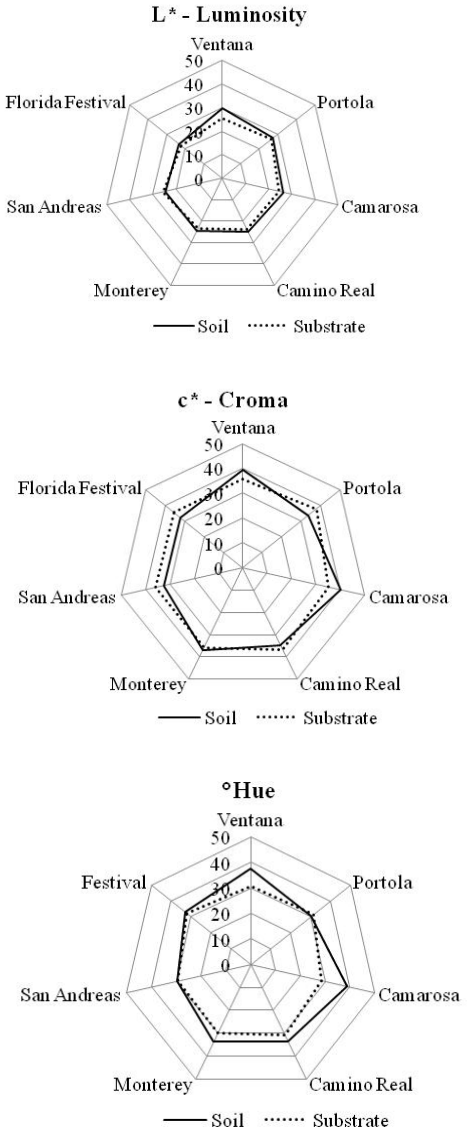

Figure 2. External color of strawberry fruits, L*, c* and °Hue values in different culture systems, Passo Fundo, Rio Grande do Sul State, cycle 2010-2011.

Color evaluation is another important attribute for strawberries because it determines the ideal conditions for harvesting and the commercialization value of the fruit. Fruit with a strong, bright red coloration are preferred, although color in most cases does not contribute an actual increase in the nutritional value or sensory quality of the product (CHITARRA; CHITARRA, 2005).

Conclusion

The cultivation of strawberries grown in two different media systems in a greenhouse generated the following conclusions:

The yield per strawberry plant was higher in soil culture, while there was better fruit quality with regard to total soluble solids, pH, diameter, acidity, titratable total acidity and TSS/TTA ratio using the substrate system.

The greatest yield in fruits per plant, when cultivated in soil in the greenhouse, was found in cvs. Camarosa and Florida Festival. The greatest yields in soil systems were cvs. Camarosa, Florida Festival and Portola.

In the substrate system, no difference was found among the cultivars in terms of production and yield of fruits per plant.

The greatest sugar contents were those of cvs. Florida Festival, followed by Camarosa, Ventana, and San Andreas. Regardless of the cultivar, when the strawberry was grown in substrate, sweeter fruits were obtained.

Fruits, regardless of cultivar or media system used, displayed a dark red color and less chromatics.

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