Camino Real and Camarosa strawberries in reduced plant spacing

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Abstract – The strawberry cultivars Camino Real and Camarosa are widely cultivated in Brazil, but they differ in vigor of plants. The objective of this work was to evaluate the hypothesis that they respond differently to reduction in plant spacing and the cultivar Camino Real can be planted in higher plant densities with gains in yield. Experiments were conducted in three harvest seasons testing both cultivars in spacing of 30cm between rows and 20 to 40cm between plants. The berries production, precocity, vegetative growth, soluble solids content and phytosanitary losses were evaluated. The cultivars responded differently to the spacing, with higher yield per m² in smaller spacing. Nevertheless, no effect of spacing was found on soluble solids and phytosanitary losses. It is concluded that Camarosa and Camino Real respond differently to reduction in plant spacing, but smaller spacing increases yield of both, with no effect on soluble solids content or in losses due to pests in fruits.

Index terms: *Fragaria* x *ananassa*; density*;* yield; growth.

Morangueiros Camino Real e Camarosa em espaçamentos de plantas reduzidos

Resumo – Os cultivares de morangueiro Camino Real e Camarosa são amplamente cultivados no Brasil, mas diferem no vigor das plantas. O objetivo deste trabalho foi avaliar a hipótese de que eles respondem de maneira diferente à redução no espaçamento de plantio, e que Camino Real pode ser plantado em densidades maiores com vantagens no rendimento. Os experimentos foram executados em três safras, comparando os dois cultivares em espaçamentos de 30cm entre linhas e 20 a 40cm entre plantas. Foram avaliados a produção de morangos, o crescimento vegetativo, o teor de sólidos solúveis e as perdas fitossanitárias. Os cultivares responderam de formas diferentes aos espaçamentos, mas ambos produziram maior quantidade em espaçamentos menores. Apesar disso, não foram observados efeito do espaçamento nos sólidos solúveis e perdas fitossanitárias. Conclui-se que Camarosa e Camino Real respondem de maneiras diferentes à redução do espaçamento de plantio, mas ao reduzi-lo se aumenta o rendimento dos dois, sem afetar o teor de sólidos solúveis nem as perdas de morangos por pragas e doenças.

Termos para indexação: *Fragaria* x *ananassa;* densidade; rendimento; crescimento.

Introduction

The strawberry (*Fragaria* x *ananassa* Dutch) is a perennial, not woody plant frequently cultivated in an annual basis. The plants are composed by one main and some secondary crowns, which are compressed steams from where flowers, leaves and runners are set. Secondary crowns are branches of the main crown that are emitted following stimuli of short days and bland temperatures. Each crown can emit more than one cluster of inflorescences.

Planting strawberry in high density leads to a reduction in number of leaves, leaf area, dry mass and number of crowns, mainly in the end of the productive cycle. Also, closer plant spacing can increase disease incidences, like for gray mold (*Botrytys cinerea*) (LEGARD et al., 2000). On the other hand, productivity are increased and the mean berry size is not affected (PÉREZ DE CAMACARO et al., 2005; PARANJPE et al., 2008). Spacing recommended by the literature for field-grown strawberry in Brazil varies from 30 to 40cm between plants (REBELO & BALARDIN, 1997; RONQUE, 1998; SANTOS & MEDEIROS, 2005). Mógor et al. (2014) recommend 30 and 40cm for less and more vigorous cultivars, respectively.

Among the short-day strawberry cultivars used in Brazil, Camarosa has shown the highest yields (STRASSBURGER et al., 2010; VIGNOLO et al., 2011). However, it could be excessively vigorous (SANTOS, 2003). The cultivar Camino Real, on the other hand, is a less vigorous, compact plant which produces biggest berries (VIGNOLO et al., 2011), an advantage to local production systems. So, the objective of this work was evaluate the hypothesis that Camarosa and Camino Real respond differently to a plant spacing reduction since they differ in vigor, and Camino Real can be planted in higher plant densities with advantages in yield.

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Material and methods

Three experiments were performed in 2013/14, 2014/15 and 2015/16 seasons, in Xanxerê, SC, Brazil (730m of altitude; Cfb climate – Köppen). In 2013/14 the soil for the experiment had, 45% clay, pH 6.9, 5% organic matter, 137mg dm^{-3} of P and 336mg dm^{-3} of K. In the next harvest season it had 38% clay, pH 6.7, 2.9% organic matter, 186mg dm^{-3} of P and 360mg dm^{-3} of K. In 2015/16 clay content was 32%, pH 6.6, 5% organic matter, 168mg dm^{-3} of P and 392mg dm^{-3} of K.

The experiments were installed under a transparent, 150µm low density polyethylene (LDPE) sheet as a high tunnel, measuring five meters in width. Under the tunnel, three 90-cm wide beds were built, with three drip irrigation lines. The design was in random blocks, with three replicates. Each block was composed by one of the three beds in the tunnel, in order to control the effects of the position in the tunnel: center, right or left. The treatments tested were the cultivars of strawberry Camarosa and Camino Real, combined with five plant spacing: 20x30, 25x30, 30x30, 35x30 and 40x30cm. Plants were spaced 30cm between rows and 20 to 40cm between plants (depending on the treatment) inside the row, with three rows in each bed. The experimental plots were composed by 12 plants (four plants in each row), but the first and the fourth in each row were considered borders.

Planting dates were 5/20/2013, 5/18/2014 and 5/23/2015. As pre-planting fertilization, 50g triple superphosphate and potassium chloride were added by squared meter of bed. Nitrogen (as calcium nitrate, total of 40kg N ha^{-1}) was supplied each 14 days with boron (5kg ha^{-1}). Thirty days after planting the bed surfaces were covered with a black polyethylene sheet.

Strawberries were harvested each three or four days, picking the ones with at least 75% of the surface red, from the start of the ripening until January 14th in the season 2013/14, January 12th in 2014/15 and December 29th in 2015/16. They were quantified after the following classification by size: class 35 (largest diameter higher than 35mm), class 15 (largest diameter between 15 and 35m) (PBMH & PIMO, 2009) or unmarketable as fresh fruit (diameter smaller than 15mm). Also, strawberries with rots or pest damage were classified as discarded. The yield in each class was expressed as number and fresh mass of strawberries by m^2 of bed, as well as the overall yield. The mass of fresh strawberries harvested by m^2 of bed in the first 30 days of each season was analyzed as an indicator of harvest precocity. The soluble solids content was measured in the juice in October 17th, 2013 and November 21, 2014. Samples with approximately 10 completely red strawberries per plot (depending of the availability in the day) were macerated and filtered (0.5mm mesh) and the juice obtained was submitted to refractometry. In the end of each experiment (January 14, 2014; January 12th, 2015 and December 29th, 2015), six plants from each plot were harvested for determining number of crowns and dry mass (65°C) per plant.

For each cultivar and harvest season, first and second-order linear models were fitted to the data having as explanatory variable the spacing of the plants in the rows (20, 25, 30, 35 and 40cm). The models were chosen based on the confidence intervals (95%) (CI) for its parameters: if CI for c of the equation $y = a + bx + cx^2$ (y is the dependent variable and x the spacing) did not include the zero, the second-order model was considered fitted. Otherwise, the first-order model $y=a + bx$ was considered significant when the CI for b did not include the zero. All analyses were performed in R.3.0.2 software (R DEVELOPMENT CORE TEAM, 2013).

Results and discussion

The number of strawberries harvested by m^2 decreased significantly (b<0.0, msl=95%) as the space in the row was increased from 20 to 40 cm (Figure 1A,B). However, differences were observed in the pattern of response: a first-order equation fitted better (c can be 0.0) to the response of Camarosa in the first two seasons and to the first season of Camino Real. In the other cases the response was better explained by a second-order equation ($c \neq 0.0$). Using the model, the minimum yield of Camarosa was at 39.75cm between plants in 2015/2016, while with Camino Real the minimum number was with 38.55cm in 2014/15 and 40cm in 2015/16.

The fresh mass of strawberries by m^2 (Figure 2) was frequently similar to the number of strawberries. The difference was observed with Camarosa: the evidences in 2013/14 were not enough to allow stablishing a linear response to the spacing. The minimum value for mass by m^2 was estimated to correspond to the space of 39.65cm with Camarosa in 2015/16 and 38.39cm with Camino Real in 2014/15. In 2015/16, the spacing corresponding to the minimum yield m^{-2} of Camino Real was 40.00cm.

When class-35 strawberries were evaluated, the number yielded by Camarosa in 2013/14 and 2014/15 was not significantly affected by the spacing (Figure 1C). However, in the next harvest seasons a second-order equation were fitted to the response. The spacing of 38.68cm caused the smallest number of strawberries per m^2 in 2015/16. On the other hand, the number of class-35 berries yielded by Camino Real in the three harvest seasons was better explained by a first-order equation, what means the larger is the space between plants, the smallest is the yield. The mass of strawberries in class 35 (Figure 2C,D) decreased until 40cm between plants in all cases but Camarosa in 2015/16, when the minimum mass was estimated to occur in 37.90cm.

The number of strawberries by m^2 in class 15 decreased as the spacing was enlarged (Figure 1E,F). Both cultivars responded similarly: in the first two harvest seasons a first-order equation was fitted to the number of strawberries and in 2015/16 a second-order equation. In this last season the ▶

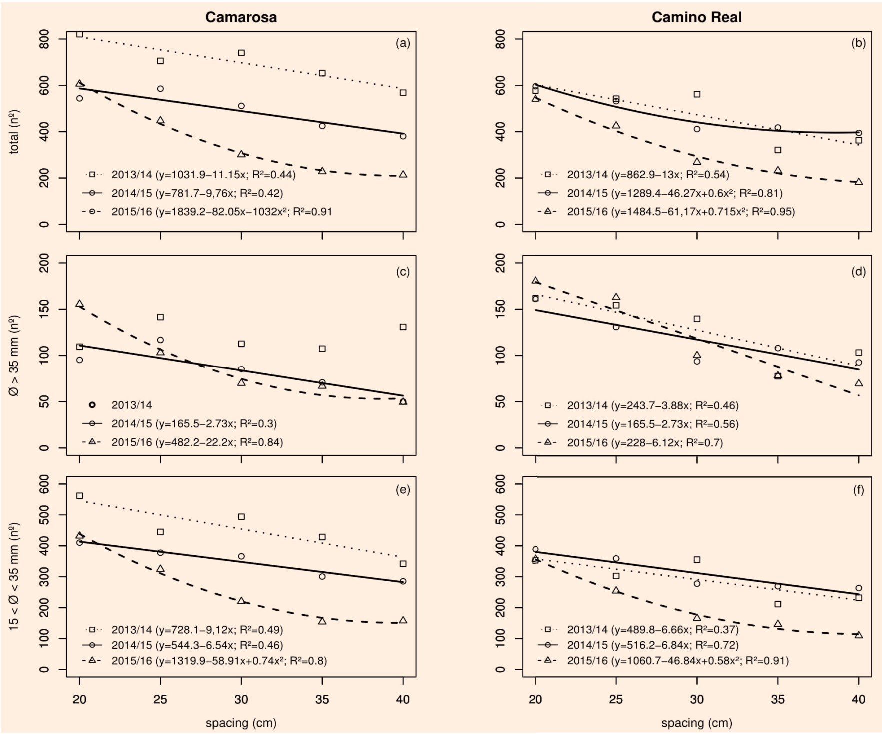

Figure 1. Number of strawberries, total (a-b) and by classes of diameter – Ø (c-f), yielded by m² of pond by the cultivars Camarosa and Camino Real as a function of spacing between plants in the row (kept constant inter-row spacing in 30cm)

Figura 1. Número de morangos, total (a-b) e por classe de diâmetro – Ø (c-f), produzidos por m² de canteiro pelos cultivares Camarosa e Camino Real em função do espaçamento entre plantas na linha (mantido constante o espaçamento entre linhas em 30cm)

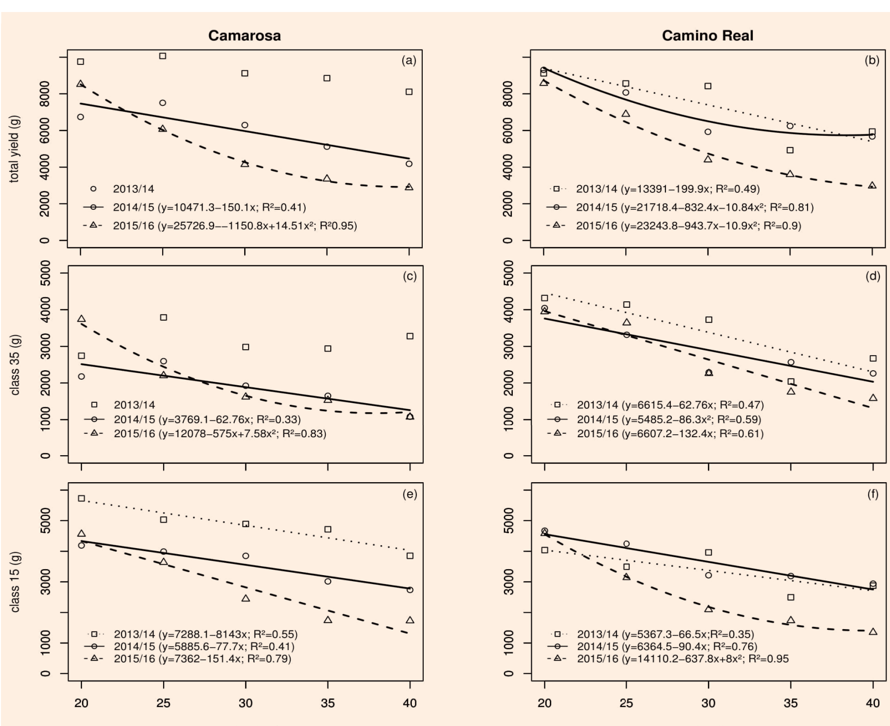

Figure 2. Strawberry yield [total (a-b) and by classes of diameter – Ø (c-f)] by m² of pond by the cultivars Camarosa and Camino Real as a function of spacing between plants in the row (kept constant inter-row spacing in 30cm)

Figura 2. Rendimento de morangos [total (a-b) e por classe de diâmetro – Ø (c-f)] por m² de canteiro dos cultivares Camarosa e Camino Real em função do espaçamento entre plantas na linha (mantido constante o espaçamento entre linhas em 30cm)

rate of decrease in yield was higher in spaces near to 20cm when compared to near 40cm. Based on the equations fitted (Figure 1E,F), it was estimated that the minimum yield of class-15 berries occurs in spacing of 36.82cm with Camarosa and 40cm with Camino Real. The mass in class 15 showed a similar response (Figure 2E,F), except in the case of Camarosa in the harvest season 2015/16, when, on the contrary of observed for number, the response was better explained by a first-order equation. The mass in class 15 yielded by Camino Real decreased until 39.86cm of spacing in 2015/16, and until 40cm in the other cases.

In relation to precocity, the mass of strawberries yielded by Camarosa, per m² of bed, in the first 30 days of harvest was explained by the equations y = 2311.4-28.04x, y = 1564.9-24.8x and y = 1407.7-23.14x, in the three seasons, respectively, while for Camino Real they were y = 3609.3-70x, y = 1795.9-33.2x and y = 1746.0-32.9x. Therefore, Camarosa early yield decreased, depending on the season, 23.14 to 28.40g m^{-2} for each centimeter of increase in spacing between plants. For Camino Real the decrease rate was higher, ranging from 23.9 to 70.0g m^{-2}.

An overall analysis of the results above reveals that high-density strawberry plantations of Camarosa and Camino Real (at least in the range of densities tested) are more productive than the conventional, agreeing with the stated by Pérez de Camacaro et al. (2004) on strawberry's higher suitability to high densities than other species. The data shown here are still followed by other authors (PÉREZ DE CAMACARO et al., 2004, 2005; STRASSBURGER et al., 2010). Among them, Pérez de Camacaro et al. (2005) tested plant densities from 16 to 100 plants m^{-2}, and the highest density resulted in the highest yield m^{-2}, since yield by plant stopped increasing when density varied from 25 to 16 plants m^{-2}. Determining what ecological factor (i.e.: water, nutrients, light, and others) was/were limiting the production is not easy. However, it is known that in some cases (depending on the spacing used) plants in smaller spacing are more efficient in using the incident radiation, which increases biomass production. In addition, a greater portion of the dry mass is converted into berries instead of crowns and leaves in higher plant densities (PÉREZ DE CAMACARO et al., 2004).

Even with higher yield by unit of area, the amount of big-size strawberries yielded was higher in spacing as narrow as 20 x 30cm. The same was observed for class-15. Some studies have reported no effect of closer planting spaces on the mean size (width and length) of strawberries (PARANJPE et al., 2008; SHAHZAD et al., 2018), which corroborate the result above. From the farmer's point of view, big-size strawberries are crucial because they are more valuable than the small ones, and the later are more difficult to sell. In the same way, for a farmer, the biggest harvest in the early days as observed in the narrower spacing is important because the offer of strawberries is limited. Consequently, the price is higher. This higher early yield happened because the yield (g m^{-2}) is proportional to the number of plants per unit of area. As plants grow, they start to compete with each other for resources; then individual plant yield tends to decrease with time.

Shoot dry mass per plant was significantly affected by the spacing (Figure 3A,B). In Camarosa the quadratic-type response prevailed. In 2013/14 the dry mass increased linearly until 34.50cm between plant in the row, and in 2014/15 until 32.20cm. In the third harvest season it increased until 40cm. Camino Real showed more dry mass per plant at 40cm of spacing, in the three harvest seasons. The number of crowns per plant (Figure 3C,D) responded similarly to dry mass. The exception was the harvest season 2014/15, when the spacing did not affect significantly the number of crowns of Camarosa. The equations fitted estimate that the maximum number of crowns in Camarosa is conferred by 32.90 and 40cm, respectively, in 2013/14 and 2015/16. With Camino Real the

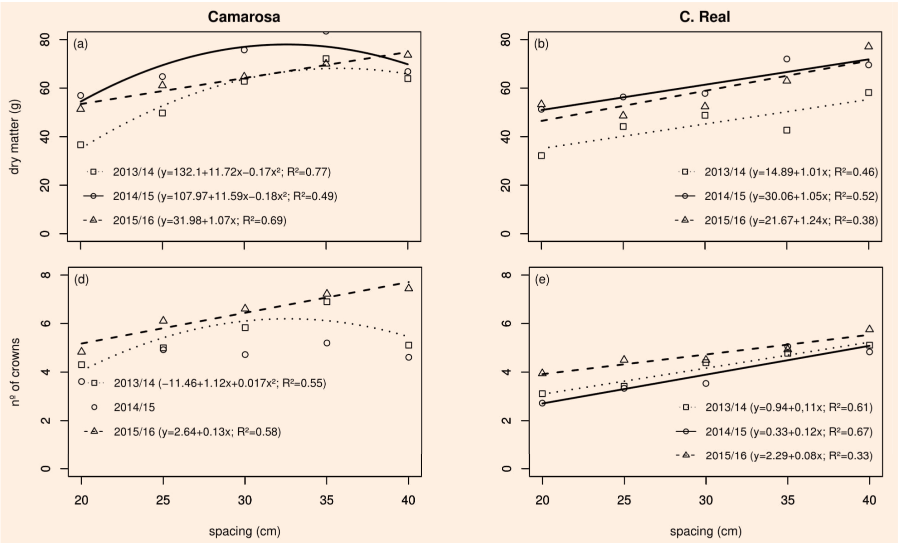

Figure 3. Shoot dry matter (a-b) and number of crows (c-d) per plant of Camarosa and Camino Real strawberries, in the end of three seasons, as a function of spacing between plants in the row (kept constant inter-row spacing in 30cm)

Figura 3. Massa seca da parte aérea (a-b) e número de coroas (c-d) por planta dos morangueiros Camarosa e Camino Real em função do espaçamento entre plantas na linha (mantido constante o espaçamento entre linhas em 30cm)

maximum value was estimated to occur with 40 cm between plants in the row.

The results on plant growth corroborate the findings on reduction in leaf area, number of leaves, dry mass of leaves and crowns and diameter of crowns by high plant densities (PÉREZ DE CAMACARO et al., 2005; BHATIA et al., 2017). However, Strassburger et al. (2010) observed that the fraction of the vegetative dry mass correspondent to crowns was smaller with 7.02 than with 3.51 plants m^{-2}. The leaf fraction, leaf area index and leaf area ratio (leaf area by dry mass unity) increased, what can rise up the yield. The diverging results in literature can be explained by genotype x environment interactions.

Crowns are lateral branches that works as individual plants. They set inflorescences which contribute to the yield of the overall plant. A reduction in yield by unit of area is related to the increase in spacing, regardless the additional crows set per plant. This indicates that the plants cannot compensate a less dense population with emission of new crowns, and so yield is reduced.

The proportion of strawberries showing pest damage or rot was not significantly affected by spacing. The mean rate observed among the treatments ranged from 0 to 1.61% of fruit loss. In terms of mass it represented a loss of 6.60 to 13.40% in 2013/14, 5.40 to 12.30% in 2014/15 and 1.00 to 3.70% in 2015/16. This data disagree with Legard et al. (2000) observations on the increase in *Botrytis cinerea* incidence as result of a rise in Camarosa plant density, in Florida (USA): incidence in 1997/98 season was 8.19 and 13.68% in the spacing of 45.70 and 22.90cm, respectively. Such incidence rates are higher than the global loss by pest and diseases observed in this work, what suggests that the plastic covering the beds prevented strawberries to get moistened and consequently infected by fungi (XIAO et al., 2001).

Soluble solids content was not influenced by the spacing. Camarosa scored 6.6 and 6.5°Brix in 2013/15 and 2014/15, respectively, and Camino Real did 6.6 and 6.8°Brix. The means presented here are similar to that observed by Brugnara et al. (2014) in various cultivars under low plastic tunnels (6.9°Brix) and higher than observed by Cecatto et al. (2013) in a greenhouse (6.9 in Camarosa and ▶

5.3° Brix in Camino Real). So, soluble solids content seems not to be a limiting factor for growing strawberry in the densities tested.

This data confirm that Camarosa is more vigorous than Camino Real, since peaked vegetative growth in narrower spacing. Besides that, regarding yield, both cultivars perform better when plants are closer until at least 20 x 30cm, but gains are more expressive with Camino Real.

Conclusions

- Reducing the spacing (increase of plant density) of Camarosa and Camino Real plants from 40 x 30cm to 20 x 30cm increases strawberry yield without affecting neither the size nor the soluble solids content nor losses by pests and diseases.
- The cultivars respond differently to the reduction in spacing.

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