

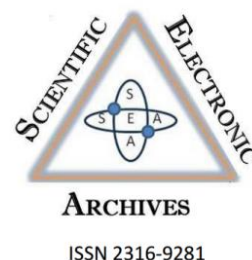
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## Plant training systems for the peach cultivar Della Nona

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**Abstract** - Cultivation of stone fruit trees in many producing countries is traditionally carried out with low planting density and training in open plant systems (pots). However, the higher density systems and training with more compact mills, for example the 'leading system', have been providing better production. The objective of this work was to evaluate the phenological, vegetative, and productive characteristics of the peach cultivar Della Nona, subjected to various training systems. The work was conducted during two production cycles where three driving systems were evaluated: 'central leader' (5.0 m x 0.8 m, 2,500 plants ha<sup>-1</sup>), 'Y shape' (5.0 m x 1.5 m, 1,333 plants ha<sup>-1</sup>) and 'vase' (5.0 m x 3.5 m, 571 plants ha<sup>-1</sup>). We showed that phenological development was not influenced by the different training systems. The training system 'central leader' gave lower cup size, lower production, but higher productivity. We conclude that the 'central leader' training system adapts to the conditions of the region and shows high productivity for the peach cultivar Della Nona.

**Keywords:** central leader, fructiculture, productivity, *Prunus persica*.

### Introduction

In the national context, Brazil stands out as one of the main producers of peaches in South America, with vast areas of cultivation especially in the southern states of the country, where climatic conditions are favorable for the development of the fruit. National peach production has gained prominence, reducing the planting area and increasing national production (IBGE, 2022).

Some training systems for peach trees optimize productivity, fruit quality and management efficiency. They range from traditional, such as a vase, to modern, such as an espalier. Combinations of hybrid rootstocks and innovations in architecture are expected to allow for greater planting density,

shorter trees and reduced costs (Manganaris G. A., 2022). Each system has its own characteristics, advantages and challenges, directly influencing crop management, fruit quality and orchard profitability. According to Pasa et al. (2017) highlight that peach cultivation in 'Central Lider' provides greater initial yield and maintains the quality of the fruits sold

The behavior of the cultivars, subjected to various trainings, can give different results (Lauri, and Grappadelli, 2014; Zec, et al., 2016). In this context, the objective of this work was to evaluate the phenological, vegetative, and productive characteristics of the peach cultivar Della Nona, subjected to various training systems.

## Material and methods

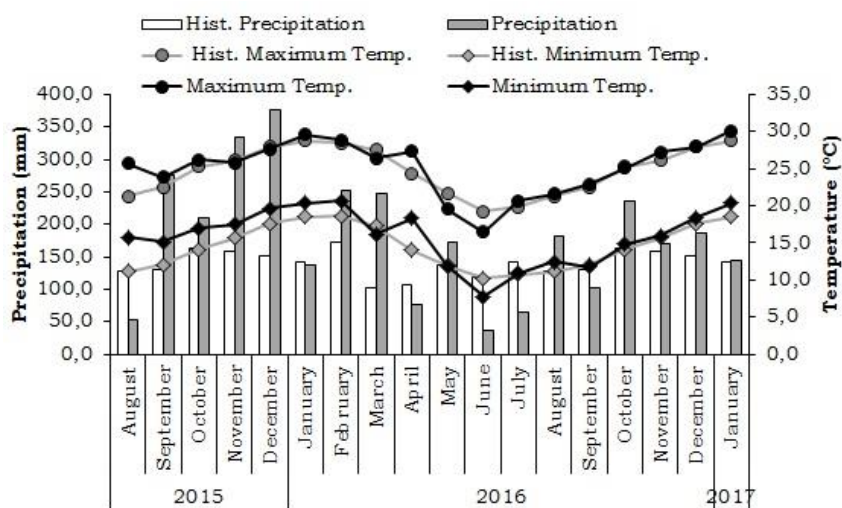
The work was conducted in a peach orchard, located at latitude 27°7'12.48"S, longitude 52°42'32.64"W, at an altitude of 600 m. The orchard was implanted in 2014, and evaluations took place during the production cycles of 2015/16 and 2016/17. The peach cultivar studied was Della Nona, grafted on a Capdeboscq rootstock, from seeds.

The site soil is a red dystroferric latosol. The climate, according to Köppen classification, is humid subtropical. The climatic conditions during the evaluation period, compared with normal climatological conditions, are shown in Figure 1.

Line spacing was kept constant at five meters for all systems. In the 'LC system, spacing was 0.8 meters between plants (5.0 m x 0.8 m, 2,500 plants ha<sup>-1</sup>); in the 'Y' system, 1.5 meters (5.0 m x 1.5m, 1,333 plants ha<sup>-1</sup>) was adopted; and in the

'vase' system, spacing between plants was 3.5 meters (5.0 m x 3.5 m, 571 plants ha<sup>-1</sup>). Fruit thinning was performed manually. All systems were managed the same way with respect to management and fertilization, being carried out according to recommendations for the respective crop.

We evaluated the following variables: a) phenology of flowering, beginning, full, and final flowering (beginning in 10% of open flowers, full bloom in 50% of open flowers, and final flowering when 90% of flowers were without petals). b) phenology of harvest, evaluated at the beginning and the end of the harvest. c) harvest duration (days), difference of days between the beginning and end of harvest. d) total cycle (days), difference of days between the beginning of flowering and the end of harvest.



**Figure 1.** Climatic conditions found during the evaluation period, compared to the normal climatological (NC) of the years 1961 to 1990, Chapecó, SC. Adapted from INMET (2017).

The treatments evaluated were the various training systems, with each system having a different spacing between plants, and different planting density. We used the training systems 'central leader' (LC), Y shape (Y) and 'vase'.

The vegetative variables evaluated were as follows: e) mean leaf area (cm<sup>2</sup>), measured 10 leaves fully expanded, collected from the four quadrants of the plant, located in the middle third, measured with a leaf area meter (brand CID Bio-Science, model CI203 + CI203CA). f) cup size (m<sup>3</sup>), measured with the following formulas: for the 'vase' and 'LC':  $D = (L \cdot E \cdot h)$ , and in system 'Y':  $D = (L \cdot h \cdot ((e1 + e2)/2))$ , where: D = cup size; L = width of the plant in the direction of the planting line (m); E = width of the cup in the direction of the interline (m); h = height of the crown, from the union of the legs to the apex (m); e1 = cup thickness in the direction of the notch on the right side (m); e2 = cup thickness in the direction of the notch on the left side leg

(m).g) green mass accumulated from branches removed with pruning (kg plant<sup>-1</sup>), representing the weight of all plant material taken from plants; h) stem diameter (mm) measured at 10 cm above the point of grafting.

Productive variables were as follows: i) fruit set (%), two branches were pre-selected in the middle part of the plant, the flowers were counted and the counting of the fruits fixed, and the ratio between flowers and fruit set; j) average number of fruits per plant; k) mean fruit mass (g), 20 fruits per plant were measured; l) dry fruit mass (%), four fruits per plant were used, determined in a forced air circulation oven (model SL-102) at 65°C, until reaching constant weight; m) equatorial diameter of fruit (mm) and n) height of fruit (mm), a sample of 20 fruits per plant was measured; o) soluble solids (°Brix), a sample of 20 fruits per plant was evaluated, using a bench refractometer (model RTD95); p) production per plant (kg plant<sup>-1</sup>); q)

estimated productivity ( $t\ ha^{-1}$ ); r) productive efficiency ( $kg\ cm^{-2}$ ), measured with the following formula:  $Ep = P/AST$ , where:  $Ep$  = productive efficiency,  $P$  = production per plant, in kg;  $CSA$  = change section area, in  $cm^2$ .

The experimental design was a randomized complete block design with three treatments and three replicates. Three blocks were used, each block being a planting line. Each replicate consisted of five plants. The data were submitted to analysis of variance by the F test. the means were compared by the Tukey test at 5% and 1% of significance.

**Results and discussion**

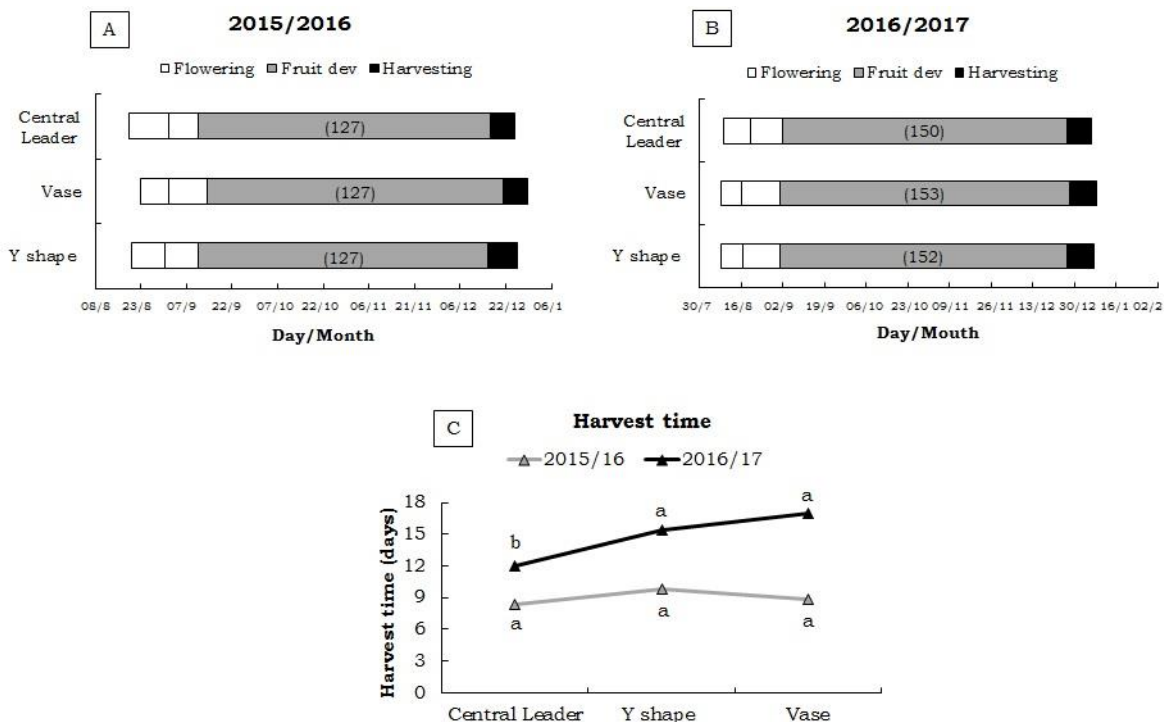
The different training systems did not alter phenological behavior in any of the productive cycles evaluated (Figure 2A, B). Only differences between the productive cycles were observed. In the 2015/16 cycle, the beginning of flowering was later and the beginning of harvesting was earlier than it was for the second productive cycle. This difference is possibly related to climatic conditions: cold intensity and a period of increased temperatures and/or youth of the plants.

In the harvesting period (Figure 2C), only the production cycle of 2016/17 was observed, in

which the 'Y' and 'vase' training systems were 33.3% longer than the 'LC'. Among the productive cycles, we observed that in 2015/16, the harvesting period was characterized by a shorter duration, compared with the 2016/17 cycle.

The use the 'vase' or 'Y' training systems allows increased availability of fresh fruit for the local consumer market and fruit grower. Peach fruits have low post-harvest durability (Cantillano, Castañeda, Almeida, and Watanabe, 2008). However, when the intention is to produce for harvest and sale outside the region of origin, standardization of the maturation point is of extreme importance for the harvest, and the LC system is most favorable.

In relation to the canopy dimension (Table 1), it can be observed that the 'vase' training system was superior to the other systems in the two production cycles. In the 2015/16 cycle, the 'vase' system was significantly superior (164.9%) to the other training systems. While in the 2016/17 cycle, we observed that 'vase' training gave 367% greater production than the 'Y' training system, and 95.5% greater than the 'LC' system.



**Figure 2.** Production cycle of peach cultivar Della Nona subjected to various training systems, in the cycles 2015/16 (A), 2016/17 (B) duration of harvest (C). Chapecó, SC, 2023. In figure A and B, the number in parentheses expresses the total productive cycle. Bar dividing flowering indicates full flowering. \*\*Different letters in the line, differing according to the Tukey test at 1% significance.

**Table 1.** Cup size, average leaf area, accumulated green mass of branches removed with pruning (MVAP) and stem diameter for various training systems peach cultivar Della Nona, in the productive cycles of 2015/16 and 2016/17. Chapecó, SC, 2023.

Training systems <sup>(1)</sup>	Cup size (m <sup>3</sup> )		Average leaf area (cm <sup>2</sup> )		MVAP (kg planta <sup>-1</sup> )		Stem diameter (mm)	
	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17
Central Leader	0.30 b**	0.90 c**	38.37 <sup>ns</sup>	33.97 <sup>ns</sup>	0.50 b**	2.38 b**	24.39 <sup>ns</sup>	36.54 b**
Y Shape	0.44 b	1.76 b	39.25	33.97	0.68 b	5.61 a	24.88	62.06 a
Vase	0.98 a	8.22 a	42.19	36.70	1.80 a	6.57 a	24.67	68.56 a
CV (%)	14.16	7.61	7.20	6.08	21.21	19.28	14.52	14.19

<sup>(1)</sup> 'Vase' = 571 plants ha<sup>-1</sup>, 'Y' = 1.333 plants ha<sup>-1</sup>, and 'Central Leader' = 2.500 plants ha<sup>-1</sup>.

<sup>ns</sup> not significant. \*\*Different letters in the column, differing according to the Tukey test at 1% significance.

For systems with high planting densities, pruning becomes relatively more frequent, since it is intended to maintain production close to the central axis of the plant. Related to this management, of course, the plant presents a smaller dimension of the canopy, since in low-density orchards, a better use of space with aerial training growth is sought.

According to Grossman and DeJong (1998), the 'LC' and 'Y' training systems obtain more light compared with the 'vase' system, on account of the high-density orchards. According to these same authors, the greater exposure to light improves production with greater area of biomass of fruits, stems, and leaves.

We observed that the training systems gave the same average leaf area (Table 1). Compared to Khromykh et al.(2020), our results differ in the average leaf area, but it is crucial to note that the use of the same rootstock in all treatments provides consistency to the data. Therefore, all have similar photosynthetic capacity (Taiz, and Zeiger, 2009). In contrast to 'Fuji' apple trees, where Lezzer et al.(2022) identified a reduction in the average leaf area with an increase in leaders, the peach tree, with mixed branches, did not exhibit significant variations. In the first year, green and dry weight of leaves were consistent, suggesting instability in plant architectures.

For branches removed with pruning in the 2015/16 cycle (Table 1), the 'vase' system gave 205.1% more green mass than did the other systems. For the 2016/17 cycle, 'vase' and 'Y' showed no difference, being 155.9% higher than 'LC'. Possibly, this superiority obtained in the lower-density systems is explained by the greater intensity of pruning for the formation of the plants at the end of winter. This ends up favoring the emission of greater number of water sprouts. While, as planting density increases, the plants are more freely-trained, with a greater number of green pruning interventions (in summer).

The interventions and the time spent with training prunings are larger in plants with a larger crown size (Glenn, Tworokoski, Scorza, and Miller, 2011), mainly due to the ideal shape (Kumar, Rawat, Rawat, and Tomar, 2010) and to increase the area of exposure to light (Grossman and DeJong, 1998), with only LC being a height limiter for the plant, which, when poorly managed/controlled, makes

thinning and harvesting activities in the higher parts difficult. He, Wang, Wei, Wang and Zhang (2008), on the relation between the relative light intensity distribution of the canopy and peach yield and quality, found that peach fruits develop better in the upper or middle layers of the crown of the plant, where it obtains more light. This demonstrates the importance of appropriate pruning interventions for each plant management system.

In the production cycle of 2015/16, the systems showed no difference with respect to stem diameter, with a mean of 24.65 mm (Table 1). However, in the 2016/17 cycle the 'vase' and 'Y' training systems presented an average of 78.7%, significantly higher than 'LC'.

The 'Y' and 'vase' training systems have a larger cup size, and a good support structure is essential for good plant support. In the 'LC' system, there is no need for a large diameter, as the energy spent increasing the stem is transferred to the formation of productive branches and fruits.

According to Stassen (2015), 'LC' allows only one-year of quality shoots (40-60 cm in length) to spiral around the leader, being ideal for high-density orchards because it allows good penetration of light. Pruning should be continuous, simple, and consistent, in small and easy steps. These actions should remove vertical and unwanted shoots, create new productive branches, and maintain plant hierarchy and balance. In this study, the productive branches were the branches of the previous cycle, being formed by and large during the months between January and April of each year, after green pruning.

For the solid soluble variables (average mass, dry mass, height and fruit diameter) there was no significant difference among the tested systems.

Fruit set was significant only for the productive cycle of 2015/16 (Table 2). We observed that the 'LC' and 'Y' training systems were significantly higher, 227.7%, superior to 'vase'. The fixation of fruits is directly related to the number of fruits per plant (Table 2). We observed that the fixation and number of fruits in the 2015/16 cycle was higher in 'LC' and 'Y'. The plants trained in these systems produced some productive branches in the first cycle, whereas for the 'vase' system, the plants were being formed.

**Table 2.** Percentage of fruit fixation (*fruit set*), average number of fruits per plant, production per plant, productivity estimated and accumulated efficiency productive, in different peach training systems for cultivar Della Nona, in the productive cycles of 2015/16 and 2016/17. Chapecó, SC, 2023.

Training systems <sup>(1)</sup>	<i>Fruit set</i> (%)		N° of fruits per plant		Production per plant (kg plant <sup>-1</sup> )		Productivity estimated (t ha <sup>-1</sup> )		Productivity accumulated (t ha <sup>-1</sup> )	Efficiency productive (kg cm <sup>-2</sup> )	
	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17		2015/16	2016/17
Central Leader	21.51 a <sup>**</sup>	58.24 <sup>ns</sup>	14.16 a*	66.47 c <sup>**</sup>	0.95 a <sup>**</sup>	6.18 c <sup>**</sup>	2.38 a <sup>**</sup>	19.69 a <sup>**</sup>	22.13 a <sup>**</sup>	0.039 a <sup>**</sup>	0.30 <sup>ns</sup>
Y Shape	18.28 a	57.90	10.72 ab	100.67 b	0.79 a	9.34 b	1.05 b	12.45 b	13.42 b	0.027 b	0.24
Vase	6.07 b	66.09	8.28 b	182.87 a	0.50 b	15.12 a	0.27 c	8.63 c	8.91 c	0.013 c	0.29
CV (%)	24.54	6.41	11.88	7.94	11.55	11.51	11.94	6.34	6.70	7.04	11.54

<sup>(1)</sup> 'Vase' = 571 plants ha<sup>-1</sup>, 'Y' = 1.333 plants ha<sup>-1</sup>, and 'Central Leader' = 2.500 plants ha<sup>-1</sup>. <sup>ns</sup> not significant. <sup>\*\*</sup>Different letters in the column, differing according to the Tukey test at 1% significance.

For the 2016/17 cycle, we observed that with the lowest planting density, the number of fruits per plant increases. The 'vase' system gave 81.6% more fruit compared with the 'Y' system, which was shown to be 51.4% greater than 'LC' (Table 2).

For the productive cycle of 2016/17, the percentage of fruit fixation did not show a difference, however, the number of fruits per plant was higher at lower density. This is related to the size of the plant. The smaller the planting density, the larger the crown size (Table 1). The larger size of the canopy provides a greater number of productive branches, consequently more fruits, despite giving the same percentage of fixation.

These results corroborate previous studies, such as those obtained by Pasa M. S. et al. (2017), who observed superiority in peach trees managed with a central leader. Similarly, research on stone fruits, such as that by Islam S. M. et al. (2022), indicated a greater number of fruits per plant in systems such as Tatura trellis compared to the Vaso system. Therefore, this study reinforces the effectiveness of two-dimensional systems in terms of fruit production compared to Y-shaped and cup systems.

In the 2015/16 cycle, the 'LC' and 'Y' systems gave significantly higher production per plant than the 'vase' system, with a mean of 74% (Table 2). This is related to the higher percentage of fixation and number of fruits per plant during the cycle. In the cycle of 2016/17, we observed that the lower the planting density, the higher the production per plant. The 'vase' training system stood out, being 61.9% greater than the 'Y' system, and 51.1% greater than the 'LC' system.

The 'vase' training system produces plants with larger size, consequently more productive branches. Mayer, Neves, Rocha, and Silva (2016) found similar results in work with peach trees in the region of Pelotas-RS, where the lower planting density provided higher production per plant. Similar results were also reported by Marini, et al. (1995), where the production of fruits per plant was higher in the 'vase' system, and the latter presented larger crown size.

The estimated productivity was higher according to the increase of the planting density, in both productive cycles (Table 2). We observed that productivity for 'LC' was significantly greater than the 'Y' system (126.7% and 58.1%), and 288.9% and 44.3% greater than the 'vase' system in the productive cycles of 2015/16 and 2016/17, respectively. Cumulative productivity followed the same behavior.

According to Marini, and Sowers (2000), and Mayer, and Pereira (2011), increasing planting density provides higher fruit yield. According to Pasa, et al. (2017), the 'LC' training system provides higher initial yield for the producer. We had similar findings in the present study, where in addition to providing greater productivity with the increase of planting density, production was anticipated, being

of extreme importance to the farmer for immediate return of investment.

In terms of productive efficiency (Table 2), there was significance only for the productive cycle of 2015/16, where the 'LC' culture system gave 44.4% higher productive efficiency than did the 'Y' system, and 107.7 % higher productive efficiency than the 'vase' system.

Due to the lower pruning intensity in the 'LC' training system, during the first productive cycle, the production per plant was superior to the other training systems, resulting in a higher productive efficiency. According to Grossman, and DeJong (1998) and Mayer, et al. (2016), the productive efficiency was the same for all systems of training and tested planting densities.

## Conclusions

- 1 - The 'central leader' training system adapts to the region and provides greater productivity in the first productive cycles, maintaining the quality of the harvested fruit.
- 2 - The various training systems do not interfere with the phenological development of the peach cultivar Della Nona.
- 3 - The 'vase' and 'Y' training systems allow fruit availability to the consumer.

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