



## Agronomic responses of grapevine 'Chenin Blanc' as a function of training systems and rootstocks

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**ABSTRACT:** The aim of this research was to study the influence of training system and rootstock on the yield, vigor and physiology of the 'Chenin Blanc' grapevine at São Francisco Valley, northeastern Brazil. An experiment was carried out on eight harvests, from 2013 to 2017, in Petrolina, in the state of Pernambuco. Grapevines were grown under two training systems, lyre and espalier, and five rootstocks: 'IAC 572', 'IAC 313', 'IAC 766', 'Paulsen 1103' and 'SO4', using a split-plot randomized block design, with training systems assigned to the main plot and the rootstock assigned to the subplot. Lyre favored an increase in the number of bunches, branches and leaf mass in the harvest of the first semester of the year, while in the second semester there were increases of 40 % in the number of bunches and 10 % in leaf mass. Lyre promoted more balanced vines, showing a better ratio between production and pruning weight (Ravaz index). The rootstocks 'IAC 766', 'IAC 313' and 'IAC 572' increased yield and bunch mass under both training systems, while 'SO4' reduced yield and vigor. The stomatal conductance and instantaneous efficiency of water use were not influenced by either the training system or the rootstock. Under tropical conditions in the São Francisco Valley, 'Chenin Blanc' grapevine may be grown under the lyre training system, preferably on the 'IAC 766' rootstock, to obtain high yields and balanced grapevines.

**Keywords:** *Vitis vinifera*, tropical viticulture, yield, vigor

### Introduction

The primary purpose of training systems in viticulture is to develop and maintain the grapevine structure with a specific shape and architecture of the canopy. Training systems have changed over time improving the microclimate by increasing the interception and distribution of solar radiation, and the exposed leaf surface (Reynolds and Vanden Heuvel, 2009; Rodrigues-Gaeta et al., 2014). The use of split canopy was proposed to meet these objectives, and the principal successful examples of these systems were: Lyre and Geneva Double Curtain (GDC).

Studies on grapevine training systems in Brazil were carried out mainly on 'Niagara Rosada', since this is the most important table grape produced in the southeastern region of the country (Vieira et al., 2006; Pedro Júnior et al., 2011; Hernandez et al., 2013). In 'Cabernet Sauvignon' and 'Syrah', the Y and GDC promoted increases in yield compared to espalier (Pedro Junior et al., 2015; Favero et al., 2010). These results demonstrated that split canopy training systems promote an increase in grapevine yield.

The rootstock and training system affect the development of the root and the vegetative canopy of the grapevine, influencing photosynthesis and carbon assimilation (Bascunán-Godoy et al., 2017). Numerous studies carried out in different Brazilian wine regions have demonstrated the influence of the rootstock on phenology, vigor, yield and grape quality (Orlando et al., 2008; Mota et al., 2009; Dias et al., 2012; Tecchio et al., 2013; Souza et al., 2015; Miele and Rizzon, 2017). The response of the

grapevine to the rootstock is specific and depends on the combination between canopy and rootstock cultivars, as well as its interaction with the edaphoclimatic conditions of each region (Vrsic et al., 2015).

'Chenin Blanc' represents 60 % of the total amount of grapes consumed in the production of white wines in the São Francisco Valley (Camargo et al., 2015). Despite its importance, there is no information in the literature about the response of the 'Chenin Blanc' grapevine to the training system and rootstocks in use nor as to the interaction between them.

The aim of the present study was to study the influence of the training system and rootstock on yield, vigor and physiological components of the 'Chenin Blanc' under tropical semi-arid conditions in the northeastern region of Brazil.

### Materials and Methods

#### Vineyard Site and Plant Material

An experiment was carried out on the 'Chenin Blanc' cultivar from 2013 to 2017, spanning eight harvests: three in the first semester and five in the second. The production cycles in the first semester were between Feb and May, while during the second semester the cycle was between July/Aug and Oct/Nov of each year.

The vineyard was located in the Experimental Field of Bebedouro, Embrapa Semiárido, in Petrolina, PE (9°08'03" S, 40°18'28" W and 370 m above sea level). The climate of the region is classified, according to Köepen, as type BswH, which corresponds to a very hot semi-arid region (Alvares et al., 2014), with an annual average air

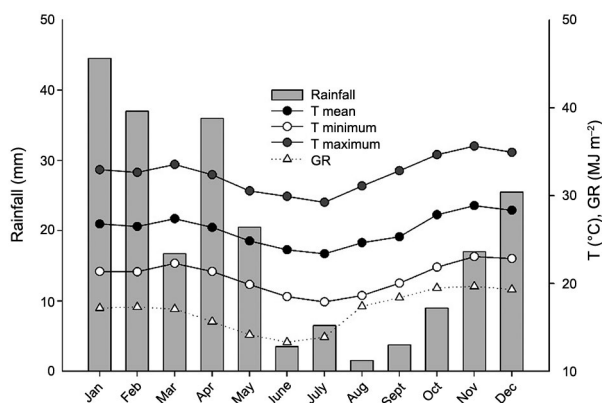
temperature of approximately 26 °C, relative humidity of 64 %, annual precipitation of about 549 mm, global solar radiation of 18 MJ m<sup>-2</sup> d<sup>-1</sup>, wind speed of 2 m s<sup>-1</sup> and reference evapotranspiration of 6 mm d<sup>-1</sup>. The average monthly variations in minimum, mean and maximum air temperature (°C), precipitation and global radiation (MJ m<sup>-2</sup>) during the study period are shown in Figure 1. The soils at the site were classified as Plistic Abrupt Eutrophic Red Argisol with a moderate A (Cunha et al., 2008).

The grapevines were grown under two training systems, espalier and lyre, both with three wires, the first one positioned 90 cm above the ground, and the third one 200 cm above ground level. Under the lyre training system, the canopy opening angle was 45°, with a distance between the two vegetation plans at the top of 1.10 m. The spacing used was 3.0 × 1.0 m (density of 3,333 plants per hectare) in the espalier and 4.2 × 1.0 m (density of 2,380 plants per hectare) in the lyre. A localized drip system supplied irrigation, with two drippers per plant, each at 0.50 m and an average flow rate of 2.10 L h<sup>-1</sup>. The water depths were calculated daily, using the ETo as determined by the Class A tank method.

The vines were trained in a bilateral cordon spur and were pruned twice a year. During the vegetative cycle, canopy management consisted of removing unnecessary shoots, lopping branches and buds, hedging, together with weed control by herbicide application, skimming between the lines, occasional hoeing and pest control.

### Treatments and experimental design

The treatments were two training systems, lyre and espalier, and five rootstocks: IAC 572, IAC 313, IAC 766, Paulsen 1103 and SO4. The experimental design was randomized blocks with split plots, the training system being the main plot and the rootstocks the subplot, totaling 12 plots. Each plot consisted of 10 plants, using the three central plants as useful plants where the evaluations were carried out.



**Figure 1** – Monthly averages of rainfall (mm); mean, minimum and maximum air temperature - T (°C); rainfall (mm) and global radiation – GR (MJ m<sup>-2</sup>) during the period of 2013 to 2017 at the experimental station of Bebedouro, Petrolina, Pernambuco.

### Vigor and Yield Components

Vegetative vigor was evaluated by the fresh mass of branches (MB) and the leaves (ML). During pruning, the removed branches were separated into branches and leaves, packed in plastic bags and weighed on a digital electronic scale (Ramuza DCR-15) to obtain the fresh masses of branches (MB) and leaves (ML) that were expressed in kg per plant. During harvesting, bunches were counted and weighed on a digital electronic scale (Ramuza DCR-15). The average results obtained were expressed in kg per plant, and the average bunch mass was configured by the ratio between total bunch mass and number of bunches per plant. The balance of the grapevine was evaluated by the ratio between the harvested grape mass and vegetative growth as measured by the fresh branch mass proposed by Ravaz (Ravaz, 1911).

During the budding and initial shoot growth phases, the number of buds, shoots and bunches were recorded to obtain the percentage of sprouting (number of buds sprouted × 100 / number of buds) and the buds' fertility (number of bunches × 100 / number of buds sprouted). These last variables were not evaluated in the first production cycle.

### Evaluation of gas exchange

In the first and second phases of fruit growth, which corresponded to 50 and 95 days after the production pruning, respectively, gas exchange was evaluated in the harvests of 2015 and 2017 on two consecutive days for each phase. For this evaluation, a portable infrared gas analyzer was used in an open system, providing saturating photon flux density of 1,100 μ mol photons m<sup>-2</sup> s<sup>-1</sup> and ambient CO<sub>2</sub> concentration. The measurements were taken on adult and healthy leaves between 8h00 and 11h00 am, the period in which the following variables were estimated: net photosynthesis (A), stomatal conductance (g<sub>s</sub>), transpiration rate (E), and instantaneous water use efficiency (A/E).

### Statistical Analysis

The variables studied were submitted to the Shapiro-Wilk normality test subject to the requirements of normal data distribution, i.e. analysis of variance (F Test, *p* < 0.05), and the averages of the single effects and interactions of the treatments were compared by Tukey test at 5 % probability. Production and data from the bunch mass for the harvest of the second semester were transformed into log (x). The gas exchange data were presented in terms of their averages with their respective standard errors.

## Results and Discussion

The lyre training system promoted an increase in the number of bunches, yield and vigor of grapevines in the harvests of both the first and second semesters of the year. However, the averages in the second semester harvests for bunch numbers, leaf mass and Ravaz index

did not meet the assumption of normal data distribution, and no analysis of variance was performed. Higher bunch numbers, branch mass, leaf mass and the Ravaz index were observed in the first semester in the 'Chenin Blanc' grapevines grown under the lyre system, while in the second semester lyre promoted increases of 40 % in bunch numbers, 10 % in leaf mass and 35 % in the Ravaz index (Table 1).

'Chenin Blanc' grapevines grown under the lyre system showed better balance between yield and vigor based on the Ravaz Index. The balance between vegetative and reproductive growth is an essential tool for achieving stable production over several harvests, enhancing economic profitability for the grape growers. Smart and Robinson (1991) suggested a ratio between 5:1 and 10:1 as optimal for moderately vigorous grapevines. Under the lyre training system, the grapevines presented values of 6.78 and 9.87, respectively, in the first and second semester, within the range recommended by those authors.

The sprouting percentage of the buds was higher under the espalier training system, but significant differences between treatments were found only for the first semester. This training system also increased the bud fertility index, independent of the period of the year, which reached values of 0.90 and 0.99 bunches per shoot, under the lyre and the espalier system,

respectively, during the harvest of the first semester, and 0.74 and 0.80 bunches per shoot for the harvest in the second semester. The bud fertility of 'Chenin Blanc' was high when compared with the average bud fertility of 0.64 bunches per shoot for eleven different table grapes evaluated in the same region (Leão et al., 2017).

Table 1 shows the influence of the rootstock on the pruning mass in the harvests of the first and second semesters, highlighting the rootstock IAC 572 as being more vigorous, with significant differences for 'SO4' in the first semester harvest and for 'Paulsen 1103' in the second semester. On the other hand, there was no rootstock effect observed in the following variables: number of bunches, leaf mass, sprouting, bud fertility and the Ravaz index.

Table 2 shows a significant interaction between the rootstock and the training system in the production per plant and bunch mass. The lyre training system favored increases in production in all rootstocks evaluated in this study and in both harvests, which represented an increase in yield of 20 % and 27 % for the first and second semester harvest, respectively, when compared to the espalier training system reaching under the lyre system an estimated yield of 10.6 and 13.3 t ha<sup>-1</sup>, respectively for each harvest. The yields measured in this research were comparable to those reported for the 'Chenin Blanc' cultivar, of 15.3 t ha<sup>-1</sup> and 11.2 t ha<sup>-1</sup>, in studies conducted under different

**Table 1** – Average values and coefficients of variation for number of bunches, pruning mass per plant (kg), leaf mass per plant (kg), sprouting (%), buds' fertility index (bud<sup>-1</sup> bunches) and Ravaz index (production pruning mass<sup>-1</sup>) in the 'Chenin Blanc' grapevine grown under the lyre and espalier systems on five rootstocks, from 2013 to 2017.

Training system	Number of bunches	Pruning Mass		Leaf Mass	Sprouting	Fertility Index	Ravaz Index
		kg					
Average yields of the 1 <sup>st</sup> semester							
Espalier	16.84 b	0.455 b	0.766 b	92.05 a	0.99 a	7.15 b	
Lyre	25.40 a	0.577 a	0.902 a	89.32 b	0.90 b	9.87 a	
Average	21.12	0.516	0.834	90.69	0.95	8.51	
CV (%)	9.71	16.13	12.42	8.56	11.96	24.45	
Rootstocks							
IAC 313	21.52 <sup>ns</sup>	0.519 ab	0.796 <sup>ns</sup>	92.30 <sup>ns</sup>	1.02 <sup>ns</sup>	8.04 <sup>ns</sup>	
IAC 572	22.54	0.608 a	0.867	92.71	0.94	8.88	
IAC 766	21.54	0.551 a	0.885	93.32	0.97	9.38	
P1103	20.03	0.410 ab	0.814	89.60	0.92	7.52	
SO4	19.96	0.409 b	0.806	85.52	0.90	8.75	
Average yields of the 2 <sup>nd</sup> semester							
Espalier	15.01	0.568 b	0.772	76.58 <sup>ns</sup>	0.80 a	4.41	
Lyre	25.08	0.737 a	0.858	74.01	0.74 b	6.78	
Average	20.04	0.653	0.815	75.29	0.77	5.60	
CV (%)	–	18.87	–	8.47	9.46	–	
Rootstocks							
IAC 313	20.53	0.680 ab	0.830	70.80 <sup>ns</sup>	0.75 <sup>ns</sup>	5.27	
IAC 572	21.15	0.762 a	0.795	74.12	0.78	5.04	
IAC 766	21.02	0.639 ab	0.800	79.45	0.81	6.17	
P1103	20.11	0.554 b	0.781	75.28	0.78	7.32	
SO4	17.41	0.628 ab	0.870	76.81	0.74	4.19	

<sup>1</sup>Means followed by the same lowercase letter in the column do not differ as per the Tukey test ( $p < 0.05$ ); <sup>2</sup>ns = not significant (F test  $p > 0.05$ ); <sup>3</sup>Data of number of bunches, leaf mass and Ravaz index in the second semester did not present normal distribution; therefore, they were not submitted to analysis of variance.

**Table 2** – Average values and coefficients of variation for production (kg per plant) and bunch mass (g) for ‘Chenin Blanc’ grapevine grown under the lyre and espalier systems on five rootstocks, from 2013 to 2017.

Rootstocks	Production (kg per plant)			Bunch Mass (g)		
	Espalier	Lyre	Average	Espalier	Lyre	Average
	Average yields of the 1 <sup>st</sup> semester					
IAC 313	3.24 aB	4.24 abA	3.74 ab	174.83 aA	164.50 bA	169.67 b
IAC 572	2.84 aB	4.60 aA	3.72 ab	175.53 aA	169.93 bA	172.73 b
IAC 766	2.81 aB	5.28 aA	4.04 a	174.82 aA	206.41 aA	190.62 a
P1103	1.96 bB	4.88 aA	3.42 b	138.75 bB	164.50 bA	161.94 b
SO4	2.03 bB	3.32 bA	2.67 c	133.40 bA	129.67 cA	131.54 c
Average	2.58 B	4.46 A	3.52	159.47 A	171.12 A	165.30
CV (%)	7.81	10.89		6.07	5.87	
	Average yields of the 2 <sup>nd</sup> semester					
IAC 313	3.19 aB	4.86 abA	4.02 a	206.04 aA	192.60 bcA	199.32 b
IAC 572	3.19 aB	5.75 aA	4.47 a	195.81 aA	228.14 abA	211.98 ab
IAC 766	2.88 abB	6.85 aA	4.86 a	198.44 aA	249.38 aA	223.91 ab
P1103	2.85 abB	6.68 aA	4.76 a	193.26 aB	264.87 aA	229.06 a
SO4	2.32 bB	3.77 bA	3.04 b	177.24 aA	174.41 cA	175.83 c
Average	2.88 B	5.58 A	4.23	194.16 A	221.88 A	208.02
CV (%)	11.42	11.30	5.31	1.39	1.72	

<sup>1</sup>Means followed by the same lowercase letter in the column do not differ as per the Tukey test ( $p < 0.05$ ); <sup>2</sup>Means were transformed into log (x) in the harvest of the second semester.

environmental and management conditions, respectively, in Elsenburg, South Africa (Archer and Schalkwyk, 2007) and Washington state, USA (Keller et al., 2005). The results obtained in this research are in accordance with results reported for ‘Cabernet Sauvignon’ (Pedro Júnior et al., 2015) and ‘Niagara Rosada’ cultivars (Hernandes et al., 2013), where the lyre system increased yield compared to the espalier system.

Under the lyre training system, ‘Chenin Blanc’ grapevines showed a reduction in yield only in the SO4 rootstock in both the first and the second semester of the year, and no statistically significant differences were observed in the other rootstocks. The average yield of the two training systems was higher in the ‘IAC 766’ rootstock in both harvests, but did not differ significantly from the ‘IAC 313’ and ‘IAC 572’ rootstocks in the first semester, while in the second semester the production in this rootstock was only different in ‘SO4’. The highest production values per vine were obtained for the ‘IAC 766’ rootstocks under the lyre training system and for the second semester harvest, which reached 6.85 kg per vine and were similar to the production reported by Camargo et al. (2011) in the same cultivar grafted on ‘IAC 572’ in the São Francisco Valley.

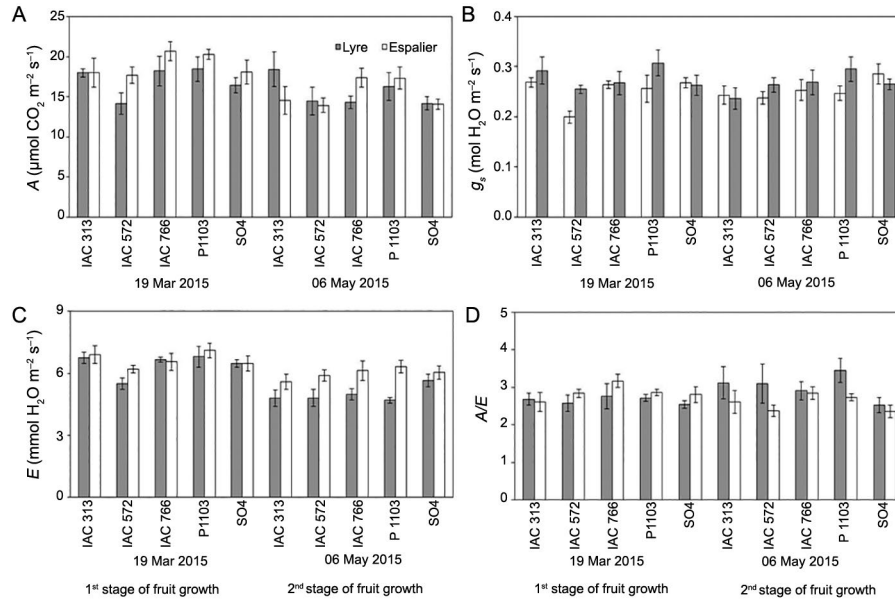
The training system had little influence on the bunch mass, but was greater in the grapevines grown under the lyre system and grafted on the ‘Paulsen 1103’ rootstock. The ‘IAC 766’ and ‘Paulsen 1103’ rootstocks were highlighted under the lyre training system where maximum values for the bunch mass were obtained for both harvests in the year.

Gas exchange evaluations in 2015 (Figure 2) revealed a trend to higher values of net photosynthesis (Figure 2A) and leaf transpiration (Figure 2B) in vines

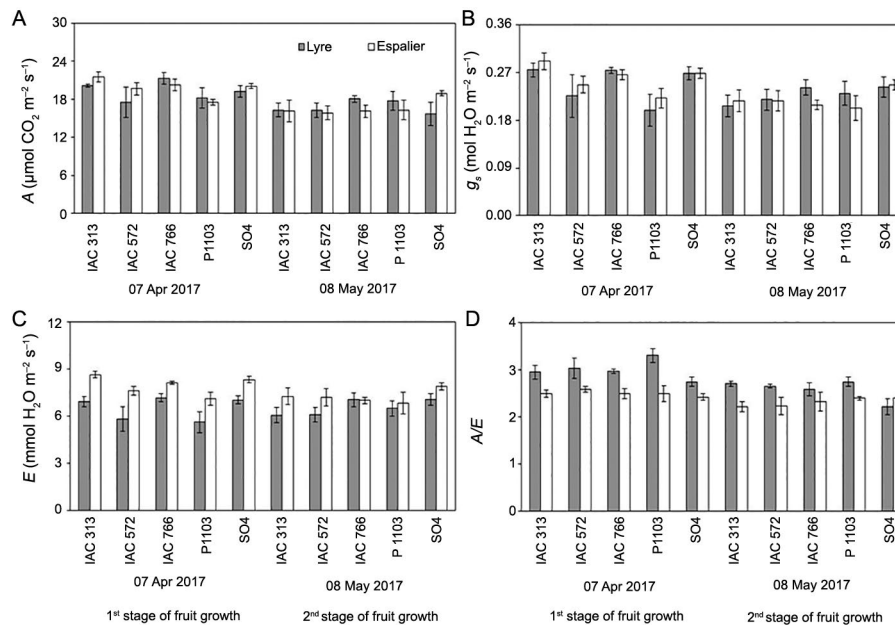
grown under espalier, which may have been related to greater exposure of the leaves to the intensity of solar radiation for photosynthesis. However, no differences were observed in stomatal conductance values (Figure 2C) nor the instantaneous efficiency of water use (Figure 2D) between vines grown under either lyre or espalier.

In 2017, no effects were observed on photosynthesis or stomatal conductance (Figure 3A and 3B). Only the transpiration values (Figure 3C) were higher in the vines grown under espalier, with lower values in the instantaneous efficiency of water use (Figure 3D). As regards the rootstock, there was no effect on gas exchange on vines grown either under lyre or espalier in the two production cycles evaluated, which agree with the results described by Norberto et al. (2009) evaluating gas exchange in the ‘Folha de Figo’ grapevine grown under lyre and espalier and Sanchez-Rodriguez et al. (2016) in ‘Niagara Rosada’ under lyre and Y where they found no positive effect on the training systems in the gas exchange of grapevines.

Higher values in transpiration in grapevines grown under espalier may be due to the greater exposure of leaves to the incidence of solar radiation (Figure 1), since the vineleaves grown under espalier have less self-shading than leaves grown under lyre, and are more susceptible to the direct action of global radiation. Due to the significant influence of air temperature, transpiration in plants grown under espalier avoids thermal stress and closed stomata, and promotes the entry of CO<sub>2</sub> with no increase in photosynthesis values. Chaves et al. (2016) emphasized that the study of climatic variables in the physiological process is fundamental to the ability to indicate a more suitable training system for the growing of the ‘Chenin Blanc’ grapevine in the São Francisco Valley region. The



**Figure 2** – Net photosynthesis values (A) [A], stomatal conductance ( $g_s$ ) [B], transpiration (E) [C] and instantaneous water use efficiency (A/E) [D], observed in plants of the ‘Chenin Blanc’ grapevine, grafted on five rootstocks and cultivated under lyre (grey column) and espalier (empty column), in the first and second stages of fruit growth in the 2015 cycle. Each column represents the average data for two evaluation days in four plants, and the bars indicate average standard error.



**Figure 3** – Net photosynthesis values (A) [A], stomatal conductance ( $g_s$ ) [B], transpiration (E) [C] and instantaneous water use efficiency (A/E) [D], observed in plants at the ‘Chenin Blanc’ grapevine, grafted on six rootstocks and cultivated under lyre (grey column) and espalier (empty column), in the first and second stages of fruit growth in the 2017 cycle. Each column represents the average data for two evaluation days in four plants, and the bars indicate average standard error.

results for vigor and yield in grapevines were higher under lyre than espalier, which may be associated with more A/E in lyre than espalier, an effect of major self-shading and lower incidence of solar radiation in plants

grown under lyre. This is a result of avoiding water loss to transpiration and sweating, and the application of water to cellular expansion, as evidenced by enhanced vigor and production (Table 1 and 2).

There is a higher value for net photosynthesis (Figure 2A) and leaf transpiration (Figure 2B) in vines grown under espalier. This may have been related to greater leaf exposure to the intensity of solar radiation for photosynthesis, which increases the loss of water to the atmosphere so that they do not present leaf heating that damages physiological performance. However, no differences were observed in stomatal conductance values (Figure 2C) and the instantaneous efficiency of water use (Figure 2D) between vines grown under either lyre or espalier.

## Conclusion

Under the tropical conditions of the São Francisco Valley, 'Chenin Blanc' grapevine should be grown under the lyre training system, preferably grafted on 'IAC 766' rootstock, to obtain high yields and balanced grapevines.

Gas exchanges, net photosynthesis, stomatal conductance, transpiration and instantaneous water use efficiency were little influenced by the training system and the rootstocks examined in this research study.

## Authors' Contributions

**Conceptualization:** Leão, P.C.S. **Data acquisition:** Leão, P.C.S.; Chaves, A.R.M. **Data analysis:** Leão, P.C.S.; Chaves, A.R.M. **Design of methodology:** Leão, P.C.S.; Chaves, A.R.M. **Writing and editing:** Leão, P.C.S.; Chaves, A.R.M.

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