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# Canopy management effects on 'Syrah' grapevines under tropical semi-arid conditions

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ABSTRACT: The aim of this study was to evaluate the effects of shoot topping and leaf removal practices on vegetative vigor, yield and physicochemical characteristics of the 'Syrah' grape in the semi-arid tropical climate conditions of the São Francisco River Valley in the northeast of Brazil. The experiment was conducted over five growing cycles from 2010 to 2012 in a 'Syrah' commercial vineyard in the municipality of Casa Nova, Bahia, Brazil. Treatments consisted of leaf removal once or twice during fruit set or at the beginning of bunch closure, and one or two shoot toppings of the berry when pea-sized or 10 days after berry growth had commenced. Leaf removal and shoot topping did not affect yield, plant vigor components nor the main attributes of fruit quality. In contrast, there was a seasonal effect with higher yield and better balance between production and vigor in grapes produced in the first half of 2012. The Syrah grape quality was favored in cycles in the first half of the year when its ripening phase coincided with the period of mild temperatures.
Keywords: *Vitis vinifera* L., tropical viticulture, summer pruning, shoot topping, leaf removal

## Introduction

Leaf removal and shoot topping are common practices in grapevine canopy management worldwide. In the São Francisco River Valley, in the northeast of Brazil, practices such as shoot thinning, leaf removal, and shoot topping are widely adopted. Nevertheless, little information regarding the effects of these practices on grapevines grown in tropical regions is available. It has been observed that different leaf removal methods, including both manual and mechanized, changed the canopy structure, leaf density, and the percentage of leaves and clusters, but did not affect bud fertility, shoot density, nor plant vigor (Percival et al., 1994). Early leaf removal carried out near flowering reduces the supply of carbohydrates to the fruit set/berry development and increases the leaf/fruit and skin/pulp ratios, resulting in less compact clusters which are less susceptible to disease, resulting in improved fruit composition and fewer thinned clusters (Poni et al., 2006; Poni et al., 2008; Poni et al., 2009; Intrieri et al., 2008; Austin et al., 2011). The time of leaf removal and shoot topping may affect fruit composition (Lee and Skinkis, 2013). These practices may also affect the cluster microclimate, leading to modification of, or accumulation of certain phenolic compounds (Lemut et al., 2011). Under tropical climate conditions, intensive and very late leaf removal may lead to sunburn in the grape clusters, pigmentation of the berry, and deficient maturation as a consequence of reduction in the leaf area/production ratio (Bergqvist et al., 2001).

Shoot topping is based on the principle of the reduction of apical dominance, which promotes better balance in the partitioning of carbohydrates between sources and sinks (Mota et al., 2010). Shoot topping carried out five buds above the last cluster resulted in an increase in grape production and quality when compared to shoot topping one bud above the last cluster (Dardeniz et al., 2008).

The aim of the present study was to evaluate the effects of shoot topping and leaf removal on the production components and physicochemical characteristics of the 'Syrah' grape under the semi-arid tropical climate of the São Francisco River Valley.

## Materials and Methods

### Plant material and vineyard site

The experiment was conducted over five production cycles from 2010 to 2012 in a commercial vineyard in the municipality of Casa Nova, Bahia (9°16′ S; 40°52′ W; 413.5 m altitude), in the northeast of Brazil. The pruning dates for each production cycle were: 08 Mar 2010, 30 Aug 2010, 31 Jan 2011, 27 Feb 2012 and 20 Aug 2012. Furthermore, the harvest dates were: 19 July 2010, 05 Jan 2011, 16 June 2011, 28 June 2012 and 17 Dec 2012.

The experimental vineyard consisted of 5-year old 'Syrah' grafted onto 'IAC 766' rootstock, planted in north-south rows, the vineyard lying in a north-south direction. Climate in the region is classified, according to Köeppen, as Bswh, corresponding to a very hot semi-arid region. Meteorological data were obtained from a meteorological station about 9 km distant from the experimental site, equipped with an automatic data acquisition system connected to electronic sensors for monitoring air temperature, relative humidity, solar radiation and precipitation. Vines were trained on a vertical shoot position (VSP) and spur pruned in a bilateral cordon with a load of approximately 15 buds per meter of row and formed at 60 cm above the ground with five pairs of wires used to attach the shoots. The primary shoots extended to a height of 1.2 m length above the cordon.

The between-plant spacing was 3.0 m × 1.0 m. Drip irrigation was used with 4.0 L $h^{-1}$emitters spacing 1 m between them and 3 m between dripping lines. The vines were kept evergreen, defoliated only at pruning time. Crop and plant health treatments were carried out in accordance with general recommendations for grapevines in the São Francisco Valley (Soares and Leão, 2009).

**Treatments and experimental designed**

The treatments consisted of seven combinations of leaf removal carried out at the phenological stage at the beginning of bunch closure, represented by stage L, as proposed by Baggiolini (1952), and one or two shoot toppings, carried out at the pea-berry stage and at the beginning of bunch closure, corresponding to the K and L stages, respectively (Baggiolini, 1952). The control treatment, usually adopted by the winery, consisted of leaf removal at two phenological stages. The first was carried out at fruit setting and the second at the pea-berry, J and K stages (Baggiolini, 1952), respectively. The shoot topping was done at the second leaf removal. Leaf removal, performed manually only on the east side of the plant rows, consisted of leaf removal in the region of the clusters, i.e., from the basal leaves up to the bud before the last cluster of the shoot. Shoot topping was performed 20 cm above the top wire of the trellis, maintaining a final lateral shoot length of approximately 1.5 m. The description of the timing of treatments is presented in Table 1.

The experiment was initiated as a randomized block design with four blocks and three plants per block.

**Vigor and Yield Components**

Plant vigor was evaluated by fresh matter weight of the shoots (SW) and leaves (LW) eliminated in pruning. On all pruning dates, all the shoots of the useful plants were eliminated and leaves removed. They were arranged in bundles and immediately weighed. During the bud break and initial shoot growth, the number of buds, shoots, and clusters was registered, obtaining the bud break percentage (number of sprouted buds × 100/ number of buds) and bud fertility (number of clusters × 100/number of sprouted buds). These last variables were not evaluated in the first and fourth production cycles, considering that in these two cases, there was no differentiation of treatments in the previous cycle and, therefore, there could be no effect of the treatments on these variables. At harvest, the clusters were counted and weighed. Mean cluster weight was obtained by dividing the total weight of the clusters by the number of clusters for each plant. The ratio of cluster weight to shoots' weight was calculated, thus enabling the Ravaz index to be formulated.

**Fruit composition**

Fruit composition was evaluated by measuring a number of characteristics. Berry fresh weight was determined as a mean value of 100-berries. Berry texture was measured in an electronic texturometer, evaluating the force necessary to bring about a 20 % deformation of fruit volume, which represents the minimum percentage to promote cracking on skin berry, according to preliminary tests. Soluble solids contents were obtained in an Abbe digital refractometer (AOAC, 1992). The content of sugars were obtained according to the method that uses reactive anthrone (Yemn and Willis, 1954). Titratable acidity was determined by titration in a 0.1 M NaOH solution (AOAC, 1992). Skin color was evaluated by the a* attribute, measured in a portable digital colorimeter, taking a reading from the center part of the whole grape skin. The a* values ranged from 0 to 60, and could be positive, corresponding to red coloring, or negative, which indicates green coloring. Except for the berry fresh weight, the other characteristics relating to fruit composition were made in twenty berries representative of a total of five clusters harvested in each plot.

**Statistical analysis**

The mean values of all the variables were subjected to analysis of variance (ANOVA) using the PROC ANOVA of SAS (Statistical Analysis System, version 9.2) considering the canopy management treatments as main plots and the production cycles as subplots in a split plot arrangement. The mean values were compared by the Tukey test at the level of 5 % probability.

## Results and Discussion

The climatic data were recorded for 2011 and 2012. In 2011, the annual average temperatures, maximum and minimum was 26.19 °C, 31.89 °C and 21.19 °C, respectively, while in 2012, these values were 26.70 °C, 32.61 °C and 21.26 °C, and December was the hottest month while July and August were the coldest ones (Figure 1A). Average relative humidity was 59 % and 54 % respectively in 2011 and 2012 (Figure 1B), while the average values of solar radiation were 20.70 MJ $m^{-2}$ $d^{-1}$

Table 1 – Pruning date, leaf removal, shoot topping, and harvest date in four production cycles of the Syrah grapevine, Casa Nova, BA, Brazil.

| Cycles | Days after pruning | | | |
|---|---|---|---|---|
| | T1(leaf removal and shoot topping) | Shoot topping phase 1 | Shoot topping phase 2 | Harvest |
| $1^{st}$ cycle ($1^{st}$ 2010) | 35 | 45 | 55 | 130 |
| $2^{nd}$ cycle ($2^{nd}$ 2010) | 30 | 39 | 59 | 128 |
| $3^{rd}$ cycle ($1^{st}$ 2011) | 38 | 45 | 53 | 136 |
| $4^{th}$ cycle ($1^{st}$ 2012) | 37 | 43 | 53 | 123 |
| $5^{th}$ cycle ($2^{nd}$ 2012) | 43 | 48 | 58 | 118 |

and 21.70 MJ $m^{-2}$ $d^{-1}$ (Figure 1C). With regard to rainfall, it was noted that these years were dry, and total annual rainfall was 370 mm and 137 mm respectively for 2011 and 2012, presenting values below the historical average for the region (540 mm). Furthemore, the rainfall is concentrated in the first half of the year, the second being the warmest and driest half (Figure 1D).

Significant interactions were not observed between the canopy management treatments, the production cycles and the plant vigor of the Syrah grapevine, indicating that neither leaf removal nor shoot topping resulted in differentiated responses as a function of the conditions observed in each cycle (Table 2).

Fruit yield exhibited change over the five cycles evaluated, ranging from 1.46 kg in the first half of 2010 to 4.67 kg in the first half of 2012 (Table 2), obtaining mean values of production of 2.52 kg, which correspond to estimated mean yields for the five cycles of 8.4 t $ha^{-1}$. The minimum number of clusters per plant was 13 in the first half of 2010 and maximum number was 24 in the first half of 2012 (Table 2). Evaluations of bud break and bud fertility were carried on three production cycles only, with no effect of the cycle on the bud break percentage (Table 2). Nevertheless, the percentage of bud fertility was greatly reduced in the second half of 2010, differing significantly from the other cycles evaluated. Cluster weight was less variable between the production cycles, although it exhibited higher values in the first half of 2012 (Table 2). Shoot weights were higher in the first half of 2011, while leaf weights were higher in the first half of 2012 and in the second half of 2010 observing changes in the results over the cycles for this characteristic in a way similar to that obtained for fruit yield (Table 2). This alternating behavior is common in production systems with two crop cycles per year because stable crop loads are not maintained. Therefore, excess production in one cycle may result in less vigorous and less productive plants in the following cycle, which may be related to carbohydrates and hormone driven (Smart et al., 1990).

Effects of leaf removal and shoot topping on the yield were not observed, which differed from previously published results (Table 2), although plants subjected to leaf removal and two shoot toppings exhibited production 24 % higher than those not subjected to leaf removal and with one shoot topping at stage K. Hunter (2000) mentioned that the crop practices of shoot thinning, shoot placement, shoot topping, and leaf removal favored increases in grape production and quality. Nevertheless, early manual leaf removal, before and soon after flowering, reduced production per shoot in 'Sangiovese' (Intrieri et al., 2008). In contrast, partial leaf removal did not affect yield components in 'Istrian Malvasia' (Bubola and Peršurić, 2012), which is in agreement with the results obtained in this study. Significant differences between canopy management treatments in cluster weight were not observed which is in agreement with Mota et al., (2010). On the other hand, Intrieri et al., (2008) observed that both manual and mechanical leaf removal reduced the cluster weight of the 'Sangiovesi' grapevine by 40 % and 28 %, respectively, when compared to the control.

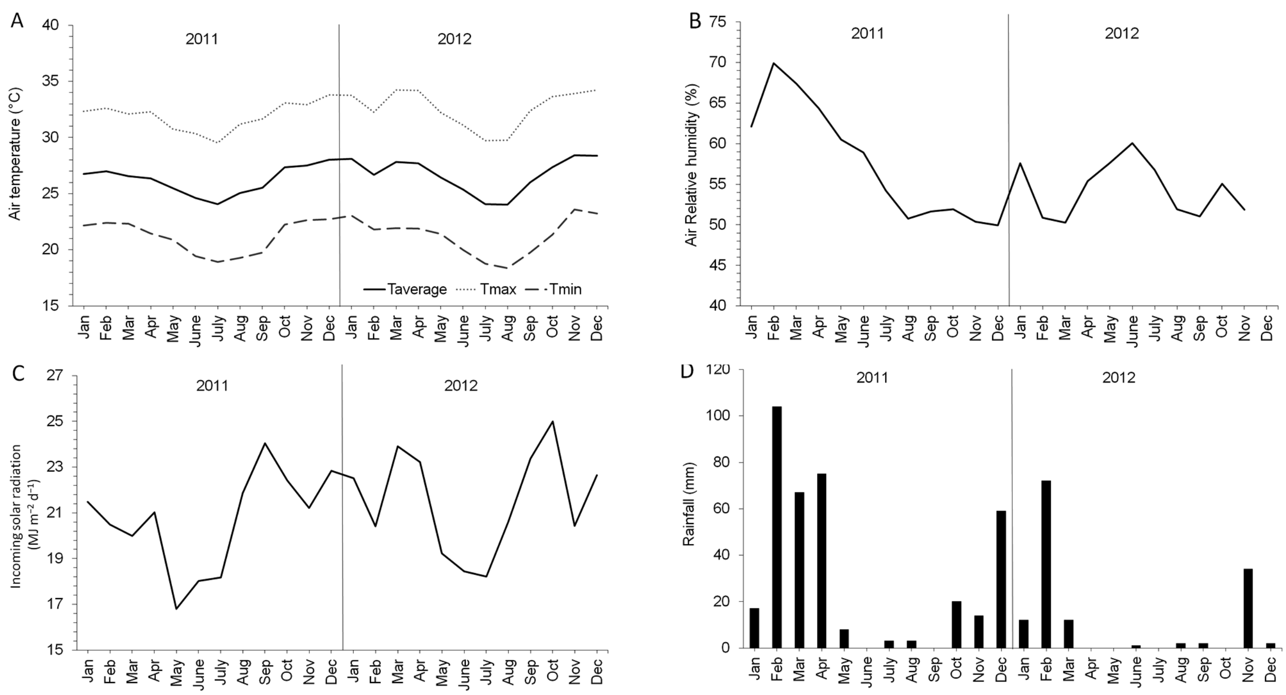


Figure 1 – Monthly average, maximum and minimum air temperatures (ºC) (A), monthly average relative humidity (%) (B), monthly average incoming solar radiation (MJ $m^{-2}$ $d^{-1}$) (C) and monthly average rainfall (mm) (D), Casa Nova, Bahia State, 2011-2012.

Table 2 – Mean values of the agronomic characteristics of Syrah grapevines subjected to the treatments of leaf removal and shoot topping in five crop seasons in the period 2010-2012, Casa Nova, Bahia, Brazil*.

| Sources of variation | PR² | NC | Spr | Fert | CW | BW | LW | RI |
|---|---|---|---|---|---|---|---|---|
| | kg | | ——— % ——— | | ——————— g ——————— | | | |
| Crop Season (Year/Semester) | | | | | | | | |
| 1st 2010 | 1.46 c | 13 b | — | — | 112 b | 486 c | 763 bc | 3.39 bc |
| 2nd 2010 | 2.20 bc | 19 a | 48ns3 | 26 c | 117 b | 622 bc | 816 ab | 4.25 b |
| 1st 2011 | 1.93 bc | 19 a | 50 | 64 a | 104 b | 836 a | 688 bc | 2.39 c |
| 1st 2012 | 4.67 a | 24 a | — | — | 198 a | 625 b | 943 a | 8.04 a |
| 2nd 2012 | 2.34 b | 19 a | 49 | 45 b | 111 b | 525 bc | 633 c | 3.88 b |
| Treatments (Leaf removal and shoot topping) | | | | | | | | |
| Control | 2.44ns | 18ns | 47ns | 4ns | 130ns | 550 b | 648 b | 5.06ns |
| T1: With leaf removal and without shoot topping | 2.66 | 20 | 49 | 45 | 131 | 786 a | 854 a | 3.88 |
| T2: With leaf removal and two shoot toppings | 2.84 | 21 | 52 | 49 | 123 | 546 b | 703 ab | 4.44 |
| T3: With leaf removal and one shoot topping in phase L | 2.39 | 17 | 49 | 44 | 139 | 666 ab | 680 ab | 4.00 |
| T4: With leaf removal and one shoot topping in phase K | 2.70 | 21 | 4 | 45 | 128 | 625 ab | 766 ab | 4.99 |
| T5: Without leaf removal and two shoot toppings | 2.50 | 20 | 48 | 38 | 121 | 623 ab | 849 a | 4.23 |
| T6: Without leaf removal and one shoot topping in phase L | 2.46 | 19 | 48 | 45 | 129 | 603 ab | 877 a | 4.36 |
| T7: Without leaf removal and one shoot topping in phase K | 2.16 | 16 | 53 | 4 | 127 | 552 b | 771 ab | 4.16 |
| CV⁴ (%) | 46.23 | 38.56 | 24.77 | 32.52 | 27.87 | 31.97 | 26.55 | 43.74 |

*For each crop season or each treatment with shoot topping or leaf removal, the mean values followed by the same lowercase letter in the column do not differ between themselves as identified by the Tukey test ($p < 0.05$); ²PR = production per plant; NC = number of clusters per plant; Spr = sprouting; Fert = bud fertility; CW = cluster weight; BW = fresh matter weight of branches; LW = fresh matter weight of leaves; RI = Ravaz Index (kg of fruit harvested/Kg of branches pruned); Control = two leaf removals, the first in the phenological phase of fruit setting (phase J), and the second in the pea-berry phase (phase K) and one shoot topping performed together with the second leaf removal.³ns = not significant ($p < 0.05$); ⁴CV (%) = coefficient of variation.

Nevertheless, as expected, leaf removal and shoot topping affected vegetative development, changing the weight of shoots and leaves, which differs from the results obtained by Bubola and Peršurić (2012), who did not find effects of leaf removal at different phenological stages on shoot weight and yield to shoot ratio.

Two leaf removals and one shoot topping at stage K (control treatment) reduced branch weight only when compared to the treatment with leaf removal without shoot topping – T2 (Table 2). On the other hand, the weight of grapevine leaves under control treatment was lower only when compared to T2, T6 and T7 treatments. In this last treatment, it was observed that the vines compensated for leaf removal by the presence of additional leaves in lateral shoots or shoots that were not topped.

The Ravaz index is an indication of vine balance as follows: a value of 5 to 10 for *Vitis vinifera* cultivars indicates the vine is balanced, a value higher than 12 indicates overcropping, while a value below 3 excessive vine size (Smart and Robinson, 1991). The Ravaz index differed significantly from one production cycle to another, observing that the crop season of the first half of 2012 was the only cycle where a satisfactory balance was obtained between yield and plant vigor. In the other cycles, the values were below the minimum limits mentioned by Smart and Robinson (1991), indicating an imbalance, a consequence of low yield and intense vegetative development. Topping and leaf removal did not have an effect on the Ravaz index (Table 2).

The berry weight, soluble solids and sugar contents were not affected by green pruning. The crop season only affected the berry weight and soluble solids contents (Table 3). It is noteworthy that for berry weight, the differences observed did not exhibit a direct relationship with the specific year of production (Table 3). However, the lowest berry weights were observed in the first half of the year, while the inverse occurred during the second half of the year. This response is due to the interaction of various factors, including regional management practices, which involve intensive adoption of inputs and successive production cycles, with limited periods of rest, as well as the climatic conditions of the time of year. In this respect, the cycles of both the first and second half of the year were different. In the first half of the year, the mean temperature was 24 °C during the fruit maturation and harvest period, while in the second half of the year, the temperatures were warmer (Figure 2A). Likewise, global irradiance predominant in the cycles of the first half of the year showed a tendency to reduce from 64 DAP. For the second half of the year, the responses were different and a tendency for global irradiance near harvest to increase was observed (Figure 2B). With its specific climatic features compared to most of the grape growing regions of the world, it is expected that the São Francisco Valley has plant responses and grape composition which acquire particular qualities according to the period of the year in which the grapes are being produced. These characteristics have been associated with high temperatures throughout the year, low daily temperature range and high insolation, as elements

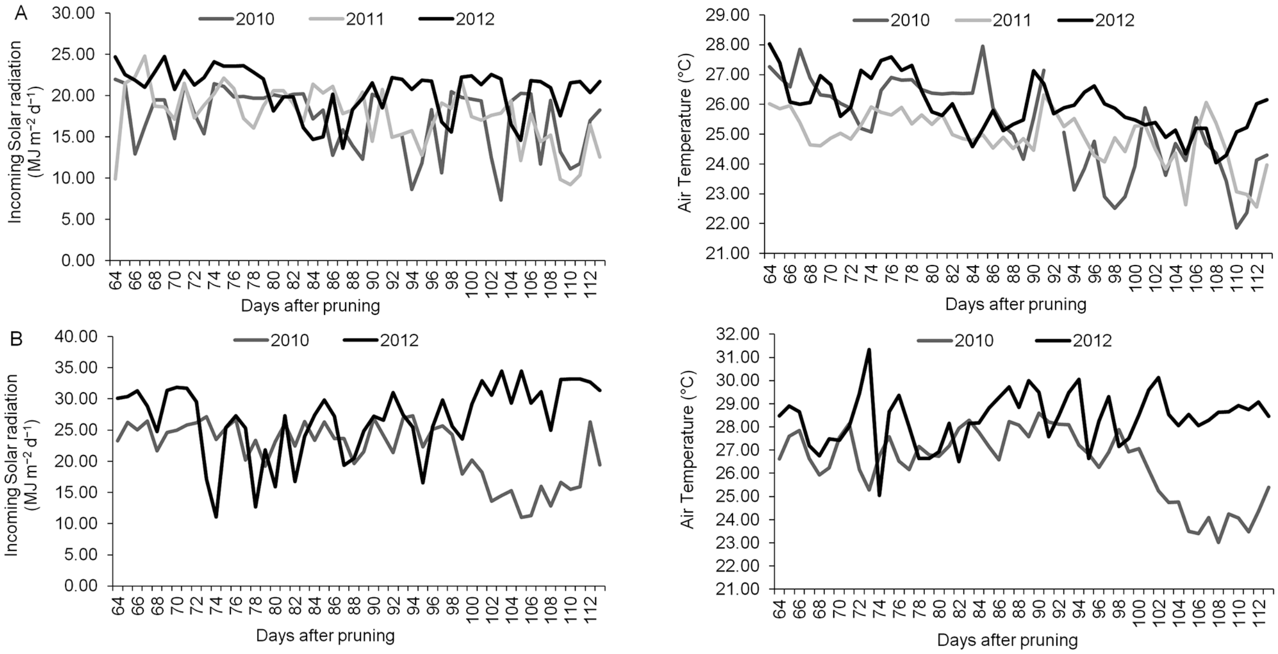


Figure 2 – Incoming global solar radiation and mean air temperatures in the period from 64 to 112 days after pruning of the Syrah grapevine corresponding to the cycles carried out in the 1st half (A) and 2nd half (B) of the year, Casa Nova, Bahia, Brazil.

Table 3 – Mean values of berry weight, resistance of compression force, soluble solids content (SS) and sugars content (SC) of the berries of Syrah grape subjected to leaf removal and shoot topping treatments in five crop seasons in the period from 2010 to 2012, Casa Nova, Bahia, Brazil*.

| Sources of variation | BeW | RCF | SS | AS |
|---|---|---|---|---|
| | g | N | °Brix | g 100 g$^{-1}$ |
| Crop Season (Year/Semester) | | | | |
| 1st 2010 | 1.76 b | - | 22.3 b | 21.53$^{ns}$ |
| 2nd 2010 | 1.89 a | 1.87 d | 22.4 b | 21.71 |
| 1st 2011 | 1.61 c | 2.89 b | 22.6 b | 21.67 |
| 1st 2012 | 1.37 d | 3.13 a | 22.4 b | 21.64 |
| 2nd 2012 | 1.83 ab | 2.36 c | 23.6 a | 22.23 |
| Treatments (Leaf removal and shoot topping) | | | | |
| Control | 1.61$^{ns}$ | 2.67$^{ns}$ | 22.8$^{ns}$ | 21.65$^{ns}$ |
| T1: With leaf removal and without shoot topping | 1.70 | 2.62 | 22.4 | 21.43 |
| T2: With leaf removal and two shoot toppings | 1.64 | 2.57 | 22.9 | 22.02 |
| T3: With leaf removal and one shoot topping in phase L | 1.68 | 2.52 | 22.3 | 21.50 |
| T4: With leaf removal and one shoot topping in phase K | 1.67 | 2.54 | 23.1 | 22.20 |
| T5: Without leaf removal and two shoot toppings | 1.74 | 2.59 | 22.7 | 21.79 |
| T6: Without leaf removal and one shoot topping in phase L | 1.74 | 2.49 | 22.7 | 21.80 |
| T7: Without leaf removal and one shoot topping in phase K | 1.75 | 2.50 | 22.5 | 21.64 |
| CV (%) | 8.63 | 9.09 | 6.25 | 6.43 |

*For each crop season or each treatment with shoot topping and/or leaf removal, the mean values followed by the same lowercase letter in the column do not differ between themselves as identified by the Tukey test ($p < 0.05$). BeW = berry weight; RCF = resistance to compression force; SS = soluble solids content; AS = content of soluble sugars. Control = two leaf removals, the first in the phenological phase of fruit setting (phase J), and the second in the pea-berry phase (phase K) and one shoot topping performed together with the second leaf removal. ns = not significant. CV (%) = coefficient of variation.

that stimulate the synthesis of reserve substances in plants. On the other hand, these stimuli require a large intake of inputs that enhances the productive potential of plants and fruit quality. Specifically dealing with green pruning in vines, it is essential to mention the phenomenon called photosynthetic compensation, reported by Intrieri et al., (2008). They suggested that berry size and weight were unaffected by defoliation in 'Sangiovese' grapes because the remaining leaves may be able to compensate for the carbohydrate demand.

The highest soluble solids content was observed in grapes harvested in the second half of 2012 (Table

3). However, the accumulated sugar level did not vary from one crop season to the next, suggesting that other soluble compounds such as organic acids and a number of phenolic compounds, could have influenced the soluble solids content. In a study involving the Pinot Noir cultivar over two production cycles, Lee and Skinkis (2013) reported that the use of leaf removal, undertaken at the time of flowering or when the berry is pea size, did not affect grape maturity, determined through berry weight, pH, and soluble solids content. Lemut et al., (2011) reported, for the same cultivar, that if this practice is undertaken at the time of the *veraison* (the onset of ripening), berry weight increases. The authors considered that this increase may be the result of the greater accumulation of a number of compounds, including certain phenolic groups.

Lee and Skinkis (2013) highlighted that, in spite of the ability of leaf removal to change production, fruit composition, cluster morphology, photosynthetic capacity of the plant, and the carbohydrate reserves, the different intensities of leaf removal regulate the response. This is a consequence of the differential effect in carbohydrate metabolism in the grapevine. In addition to the intensity of leaf removal, the time period and frequency with which it is carried out, the cultivar, rootstock used, production period in tropical climates, vine training system, spacing between plants and rows, and the reserves available in the roots also determine the responses (Intrieri et al., 2008; Poni et al., 2008; Poni et al., 2009; Lee and Skinkis, 2013).

Titratable acidity of the Syrah grapes was affected by the interaction between the treatments with shoot topping and/or leaf removal and the crop seasons (Table 4). The results indicate that titratable acidity of the grapes was more stable in the crop seasons in the first half of the year, except in those that were harvested from plants that had received a single shoot topping at the stage when the berry was pea size – K (T5 and T8). Of the crop seasons under study, those conducted in the second half of 2012 were characterized by fruits with less titratable acidity. This crop season exhibited a higher temperature range with a peak (31.5 °C, approximately), during berry development (Figure 2). These high temperatures in comparison with other studied crop seasons influence the plant and fruit metabolism. Admittedly, increases ln temperature induce high respiratory rates, which promote an intense breakdown of compounds that act as respiration substrates, especially certain sugars and organic acids. The grapes harvested in the second half of 2012 stood out from the other crop seasons, observing that the treatments in which shoot topping had been carried out earlier (stage K), whether conducted only at this stage or in association with shoot topping at stage L, regardless of the use of leaf removal, resulted in lower titratable acidity values (Table 4). Soluble solids content and the titratable acidity of the grapes, as in the case of weight and volume, are not affected by practices that promote different degrees of shading in the clusters, as showed by Jeong et al., (2004).

The berry weight, the berry resistance to compression force, was not affected by treatments involving canopy management (Table 3). This variable, which has a close relationship to the turgescence of plant tissue and the cell wall composition, can be considered in winemaking as it may be associated with the degree of ease of grape must extraction during the pressing process. The production cycles had only one effect on this variable, namely, less resistance in the berries harvested in the crop seasons of the second half of the year. It is possible that the greater temperatures, registered near harvest in the cycles related to these periods of the year and associated with the practice of irrigation restriction, contribute to this response.

Grape color evaluated by the a* attribute was affected by combined action of the use of leaf removal and/or shoot topping and the production cycles (Table 4). It was observed that the use of leaf removal, except for the treatment when it was combined with shoot topping carried out at stage K, allowed for values of a* within a more regular range in the first half cycles. In the group of cycles evaluated, the highest values were registered mainly in the grapes harvested from plants that had received only one shoot topping at stage L. Similar responses can be considered for fruit from grapevines submitted to two shoot toppings. Moreover, no leaf removal had a positive effect on grape color under the warmest crop season (second half of 2012).

The greatest values of a* are associated with red coloring, an indication of greater anthocyanin content, which is fundamental to the quality of red wine distilled from the Syrah cultivar. It is an objective measure that can be obtained quickly where suitable equipment is utilized, but there are no precise and known values for a wide variety of fruit and their cultivars. In grapes, values for this variable, determined directly on the surface of the berry, may be affected by the quantity and distribution of epicuticular wax. Even so, it is an important tool insofar as it does not lead to destruction of the fruit.

The development of fast, easy, and non-destructive methods for the evaluation of grape color allows for characterization of quality under different growing and environmental conditions, as well as support for germplasm selection, genetic breeding, and characterization and preservation of genotypes (Rustioni et al., 2013). Moreover, development of an index for quantification of pigments, valid for a wide range of cultivars, may subsidize mass evaluation of new lines, as well as overlooked varieties.

These methods may also support practical evaluations of the effect of management techniques on fruit coloring, allowing for more rapid responses and responses under field conditions.

Results from the literature also explain the relationships between crop practices which regulate

Table 4 – Mean values of titratable acidity and skin color, evaluated by the component a*, of the berries of Syrah grape subjected to treatments of leaf removal and shoot topping in five crop seasons in the period from 2010 to 2012, Casa Nova, Bahia, Brazil*.

| Sources of variation | 1st 2010 | 2nd 2010 | 1st 2011 | 1st 2012 | 2nd 2012 | 1st 2010 | 2nd 2010 | 1st 2011 | 1st 2012 | 2nd 2012 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Titratable acidity (g tartaric acid 100 mL$^{-1}$) | | | | | Skin color (a*) | | | | |
| Control | 0.62 bA | 0.74 aA | 0.61 bA | 0.57 bA | 0.45 cA | 1.98 bcAB | 5.94 aA | 2.42 bA | 2.76 bB | 1.31 cC |
| T1: With leaf removal and without shoot topping | 0.65 abA | 0.73 aA | 0.58 bcA | 0.55 cA | 0.43 dA | 1.76 bcB | 4.32 aBC | 2.04 bA | 3.41 aAB | 0.80 cC |
| T2: With leaf removal and two shoot toppings | 0.57 bcA | 0.75 aA | 0.63 bA | 0.51 cdAB | 0.42 dA | 2.22 bAB | 4.07 aC | 1.40 bcA | 3.66 aAB | 0.83 cC |
| T3: With leaf removal and one shoot topping in phase L | 0.61 aA | 0.65 aA | 0.66 aA | 0.56 aA | 0.44 bA | 2.40 bAB | 4.59 aBC | 2.15 bA | 4.24 aA | 0.70 cC |
| T4: With leaf removal and one shoot topping in phase K | 0.60 aA | 0.68 aA | 0.65 aA | 0.42 bB | 0.39 bA | 2.43 bAB | 4.10 aC | 2.04 bA | 4.29 aA | 3.82 aAB |
| T5: Without leaf removal and two shoot toppings | 0.60 bcA | 0.74 aA | 0.67 abA | 0.53 cAB | 0.42 dA | 2.72 cAB | 5.30 aAB | 2.16 cA | 4.17 bA | 4.89 abA |
| T6: Without leaf removal and one shoot topping in phase L | 0.66 abA | 0.70 aA | 0.61 abA | 0.56 bA | 0.45 cA | 3.07 cA | 6.00 aA | 1.76 dA | 4.37 bA | 3.77 bcAB |
| T7: Without leaf removal and one shoot topping in phase K | 0.59 bcA | 0.72 aA | 0.64 abA | 0.49 cAB | 0.50 cA | 2.90 bcAB | 5.47 aAB | 1.63 dA | 3.90 bAB | 2.82 cB |
| CV (%) | 7.68 | 7.75 | 6.68 | 8.98 | 12.61 | 10.38 | 10.08 | 24.14 | 15.02 | 33.38 |

*The mean values followed by the same lowercase letter in the column and by the same uppercase letter in the row do not differ between themselves as identified by the Tukey test ($p < 0.05$). CV (%) = coefficient of variation.

exposure of the canopy to sunlight and the transcription of genes of anthocyanin biosynthesis enzymes. According to Jeong et al., (2004), in grapevines, these practices affected the transcription of genes of the UDP-Glucose:Flavonoid 3-O-Glucosyltransferase (*Ufgt*) enzyme. The accumulation of both mRNA of *VvmybA1*, which may control the transcription of the *Ufgt,* and the genes of other enzymes of the biosynthetic pathway of the anthocyanins, is also affected by management of leaf intensity in the canopy. Since it is possible to consider an association between anthocyanins content and a* values, it is expected that shoot topping might be an influence on the transcription of genes of enzymes involved in the synthesis of those pigments.

While recognizing the complex interactions related to the production responses of the grapevine and fruit quality, the present study highlights the particular nature of grape grown under tropical conditions. It is possible that the differentiated characteristics of the region where the study was conducted, which produces grapes at any time during the year, with a cycle regulated by control of the water depth applied through irrigation and the pruning regime, have a more determinate influence on plant response to both canopy management and the basic characteristics of fruit quality than the treatments themselves.

Finally, other compounds of the grapes may be affected by the crop practices of leaf removal and shoot topping of the vines. Presumably, the phenolic compounds are particularly affected. This possibility opens up the opportunity for future studies directed to greater detailing of the contents of these constituents in the grapes as a means of adjusting canopy management for the assessment of the quality of the grapes and, consequently, of the wines in tropical regions.

## Conclusions

Canopy management by shoot topping conducted in distinct phenological phases and by leaf removal did not affect yield, vine vigor, nor the main attributes of fruit composition. These characteristics were affected by the different and successive production cycles. The crop season of the first half of 2012 favored greatest yield, cluster weight, branch weight, and plants with a better balance between yield and vigor. The quality of the fruit produced in the first half exhibited a regular pattern. Only titratable acidity and evaluation of skin color by the a* attribute experienced interaction deriving from the canopy management treatments and the production cycles, with the use of shoot topping in the crop seasons with particular reference to the first half of each year standing out. As the canopy managements performed in the K stage, with two-leaf removals and one shoot topping, did not improve the grape color, it should be avoided during the warmest season.

## References

Association of Official Analytical Chemists - International [AOAC]. 1992. Official Methods of Analysis. 11ed. AOAC, Rockville, MD, USA.

Austin, C.N.; Grove, G.G.; Meyers, J.M.; Wilcox, W.F. 2011. Powdery mildew severity as a function of canopy density: associated impacts on sunlight penetration and spray coverage. American Journal of Enology and Viticulture 62: 23-31.

Baggiolini, M. 1952. The stages identified in the annual development of vines and their practical use = Les stades repérés dans le développement annuel de la vigne et leur utilisation pratique. Revue Romande d'Agriculture, de Viticulture et d'Arboriculture 8: 4-6 (in French).

Bergqvist, J.; Dokoozlian, N.; Ebisuda, N. 2001. Sunlight exposure and temperature effects on berry growth and composition of Cabernet Sauvignon and Grenache in the central San Joaquin Valley of California. American Journal of Enology and Viticulture 52: 1-6.

Bubola, M.; Peršurić, D. 2012. Yield components, vegetative growth and fruit composition of 'Istrian Malvasia' (*Vitis vinifera* L.) as affected by the timing of partial defoliation. Agriculturae Conspectus Scientificus 77: 21-26.

Dardeniz, A.; Yildirim, I.; Gökbayrak, Z.; Akçal, A. 2008. Influence of shoot topping on yield and quality of *Vitis vinifera* L. African Journal of Biotechnology 7: 3628-3631.

Hunter, J.J. 2000. Implications of seasonal canopy management and growth compensation in grapevine. South African Journal Enology Viticulture 21: 22.

Intrieri, C.; Filippetti, I.; Allegro, G.; Centinari, M.; Poni, S. 2008. Early defoliation (hand vs mechanical) for improved crop control and grape composition in Sangiovese (*Vitis vinifera* L.). Australian Journal of Grape and Wine Research 14: 25-32.

Jeong, S.T.; Goto-Yamamoto, N.; Kobayashi, S.; Esaka, M. 2004. Effects of plant hormones and shading on the accumulation of anthocyanins and the expression of anthocyanin biosynthetic genes in grape berry skins. Plant Science 167: 247-252.

Lee, J.; Skinkis, P.A. 2013. Oregon 'Pinot noir' grape anthocyanin enhancement by early leaf removal. Food Chemistry 139: 893-901.

Lemut, M.S.; Trost, K.; Sivilotti, P.; Vrhovsek, U. 2011. Pinot Noir grape colour related phenolics as affected by leaf removal treatments in the Vipava Valley. Journal of Food Composition and Analysis 24: 777-784.

Mota, R.V; Souza, C.R.; Silva, C.P.C.; Freitas, G.F.; Shiga, T.M.; Purgatto, E.; Lajolo, F.M.; Regina, M.A. 2010. Biochemical and agronomical responses of grapevines to alteration of source-sink ratio by cluster thinning and shoot trimming. Bragantia 69: 17-25.

Percival, D.C.; Fisher, K.H.; Sullivan, J.A. 1994. Use of fruit zone leaf removal with *Vitis vinifera* L. cv. Riesling grapevines. I. Effects on canopy structure, microclimate, bud survival, shoot density, and vine vigour. American Journal of Enology and Viticulture 45: 123-132.

Poni, S.; Bernizzoni, F.; Civardi, S. 2008. The effect of early leaf removal on whole-canopy gas exchange and vine performance of *Vitis vinifera* L. 'Sangiovese'. Vitis 47: 1-6.

Poni, S.; Casalini, L.; Bernizzoni, F.; Civardi, S.; Intrieri, C. 2006. Effects of early defoliation on shoot photosynthesis, yield components, and grape composition. American Journal of Enology and Viticulture 57: 397-407.

Poni, S.; Bernizzoni, F.; Civardi, S.; Libelli, N. 2009. Effects of pre-bloom leaf removal on growth of berry tissues and must composition in two red *Vitis vinifera* L. cultivars. Australian Journal of Grape and Wine Research 15: 185-193.

Rustioni, L.; Basilico, R.; Fiori, S.; Leoni, A.; Maghradze, D.; Faillaa, O. 2013. Grape colour phenotyping: development of a method based on the reflectance spectrum. Phytochemical Analyis 24: 453-459.

Smart, R.E.; Dick, J.K.; Gravett, I.M.; Fisher, B.M. 1990. Canopy management to improve grape yield and wine quality: principles and practices. South African Journal of Enology and Viticulture 11: 3-17.

Smart, R.; Robinson, M.; 1991. Sunlight into the wine. A Handbook for Winegrape Canopy Management. Winetitles, Adelaide.

Yemn, E.W.; Willis, A.J. 1954. The estimation of carbohydrate in plant extracts by anthrone. The Biochemical Journal 57: 504-514.