# Effects of leaf removal and cluster thinning on yield and quality of grapes (*Vitis vinifera* L., Riesling × Silvaner) in Corrales, Boyaca (Colombia)

## Efecto del deshoje y del raleo de racimos sobre el rendimiento y la calidad de las bayas de vid (*Vitis vinifera* L., Riesling × Silvaner) en Corrales, Boyacá (Colombia)

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**ABSTRACT**

The vineyards that are located in the Colombian cool tropical zone of Corrales (Boyaca department) offer grapes for the production of quality wines; to improve the crop we must know the adequate balance between the quantity of clusters and the leaf area of the plants. In order to determine the effect of leaf removal and cluster thinning on yield and quality of the clonal selection Riesling × Silvaner wine grape, it was used a completely randomized bifactorial design of 2x3. The first factor was removal of leaves (without defoliation and 60% defoliation) and the second one was cluster thinning (maintaining 66% or 33% of clusters per plant). Plants with 66% clusters and without leaf removal exhibited the highest total soluble solids content and yield of grapes, in fresh mass of clusters and fresh and dry mass of grapes. Plants without cluster thinning, but with removal of leaves, produced the lowest pH levels and total titratable acidity in the grapes. The technical maturity index was significantly higher in plants without leaf thinning; but was not affected by removed clusters. Thinning clusters is an alternative to improve production and the quality of wine grapes.

**Key works:** source/sink ratio, total soluble solids, total titratable acidity, pH, crop productivity.

**RESUMEN**

Los viñedos ubicados en la zona tropical fría de Corrales (departamento de Boyacá) ofrecen frutos para elaborar vinos de calidad; para mejorar el rendimiento se debe conocer el equilibrio adecuado entre la cantidad de racimos con relación al área foliar de la planta. Para determinar el efecto de la eliminación parcial de hojas y racimos sobre la producción y calidad de uvas de la selección clonal Riesling × Silvaner, se empleó un diseño completamente al azar bifactorial de 2x3. El primer factor fue la defoliación (sin deshoje y con deshoje del 60%). El segundo factor fue el raleo de racimos (dejando 66% ó 33% de racimos por planta). Con 66% de racimos por planta y sin deshoje se obtuvo la mayor cantidad de sólidos solubles totales, así como el mejor rendimiento de las uvas, en masa fresca de racimos y en masas fresca y seca de frutos. Plantas sin raleo de racimos, pero con deshoje, produjeron los menores valores de pH y acidez total titulable de las uvas. El índice de madurez técnico fue significativamente mayor en vides sometidas a defoliación parcial, mientras el raleo de racimos no lo afectó. El raleo de racimos es una alternativa para mejorar la producción y calidad de la uva para vinificación.

**Palabras clave:** relación fuente/vertedero, sólidos solubles totales, acidez total titulable, pH, productividad agrícola.

## Introduction

The vineyards in the cool tropical zone of Boyaca provide grapes for the production of quality wines (Quijano, 2006). However, the correct balance between the number of clusters and leaves for optimal yield under these tropical altitudinal conditions has not been investigated. Muñoz *et al.* (2002) mention that high yields reduce the quality of grapes. This is due in part to the fact that excess fruits retard sugar accumulation, as compared to plants with a lower fruit load. However, Freeman and Kliewer (1983) claim that this condition does not affect the quality of fruits and Bravdo *et al.* (1985) stated that there is an optimal amount of fruit that a plant can develop without compromising quality. In addition, plant management determines the spatial arrangement of foliage and clusters modifies the microclimate and has a fundamental impact on the regulation of photosynthetic potential, yield and grape composition (Katerji *et al.*, 1994).

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The quality of the grape is the result of the interaction of the biological (*e.g.* variety and plant health), the physical (including the soil and its management), the climate (such as temperature, precipitation, wind speed, fog conditions and/or direct and indirect solar radiation), and cultural factors (mainly the density of planting, the type of branch conduction, pruning, fruit load and vegetation management) (Disegna *et al.*, 2005; Quijano 2006; Almanza *et al.*, 2010).

A suitable balance between the photosynthetically active foliar surface and production turns out to be an important factor for obtaining quality wines (Lavin *et al.*, 2001; Salazar and Melgarejo, 2005; González-Neves and Ferrer, 2008). Muñoz *et al.* (2002) report that the common removal of leaves at the level of the clusters in vineyards alters the microclimate in the zone around the fruit and, indeed, the fruit composition. Leaf removal directly affects the leaf/fruit relationship, which, depending on the phenological stage in which it is conducted, can produce a different effect on the maturation of the fruits (Iacono *et al.*, 1995; Petrie *et al.*, 2000).

The thinning of clusters affects the source/sink ratio since the crop is limited without diminishing the leaf area. Therefore, the plant concentrates its activity on the regulation of production and quality (Matus *et al.*, 2006; Yuste *et al.*, 1997), affecting the quality of the wine (Meliá *et al.*, 1995; Parisio *et al.*, 1994). The quantity of clusters per plant affects the size of the clusters and that of the fruit, and therefore, the accumulation of sugar (Iacono *et al.*, 1995), as well as other components of the flavor of the fruit (Reynolds *et al.*, 1996) and several aspects of the vegetative growth (Edson *et al.*, 1995).

The effects of fruit load and microclimate have been studied, but only independently (Muñoz *et al.*, 2002). Changes in the microclimate produced by modifications at the level of fruit load and changes in the leaf/fruit ratio, provoked by some imposed alterations of the foliage to modify the microclimate, make the interpretation of the results difficult. Therefore, it is important to carry out investigations involving these two factors.

This study aimed to evaluate the effect of removal of leaves and clusters on the physic-chemical composition of grapevine fruits of the clonal selection Riesling × Silvaner, under the conditions of the municipality of Corrales (Boyacá, Colombia).

## Materials and methods

The field phase of the study was performed in the municipality of Corrales located at 5°50'15" N and 72°51'05" W, at an altitude of 2,450 m a.s.l. The climate of the zone is characterized by an average annual temperature of 15°C and a bimodal average precipitation of 726.6 mm year$^{-1}$ with two peaks: April-June and October-November.

Cloud cover is scarce and solar radiation is high reaching an average of 476 cal cm$^{-2}$ along 6.5 h d$^{-1}$ (Quijano, 2006). The soils are of light texture, a franco-sandy type. The life zone, in accordance with the classification of Holdrige, is low dry mountainous forest (BS-MB). Irrigation is by gravity, according to the requirements of the crop.

Grapevine of the clonal selection of *Vitis vinifera* L., variety Riesling × Silvaner from Alsace, Germany was used (Quijano, 2001a). The plants were 7 years old, planted at a distance of 1.20 x 0.90 m and trellised by three vertical wires. Pruning was done according to the simple training Guyot system. The study was conducted in the second semester of 2009.

A completely randomized bifactorial design of 2x3 with 4 repetitions per treatment was used, where the first factor was removal of leaves (without defoliation, defoliation of 60%) and the second factor was the thinning of clusters: maintaining 66% by removing one of the three clusters or retaining 33% by removing two of the three clusters). Clusters were thinned at the moment of fruit set. Thus 24 experiment units were used, four plants each. Leaf removal was conducted at the beginning of veraison, at the level of insertion of the clusters, involving the elimination of the first six leaves of every vine shoot, resulting in an average leaf area of 1,108 cm$^2$/shoot (13.293 cm$^2$/plant).

Fruit weight was determined with an Acculab VIC 612™ (Bradford, MA) scale (precision 0.01 g), with a sample of 20 fruits for every experimental unit, collected on the day of grape harvest, using five berries per cluster (two fruits each at the upper and middle part, and one from the lower part). The dry mass was obtained after submitting the fruits to a stove at 90°C until stabilization of the weight. Also, the total fruit production per plant and the average cluster weight was measured.

The chemical variables evaluated were total soluble solids (TSS, Brix grades; using a digital refractometer HI 96801 Hanna™, Woonsocket, RI), pH (potenciometer Orión™, model 420, Boston, MA), total titratable acidity (TTA; with NaOH 0.1 N up to pH 8.2 expressed in tartaric acid [AOAC, 1990]), and the technical maturity index (TMI; quotient between TSS and TTA).

For the analysis of the effects of the controlled factors on the evaluated variables a bifactorial variance analysis was

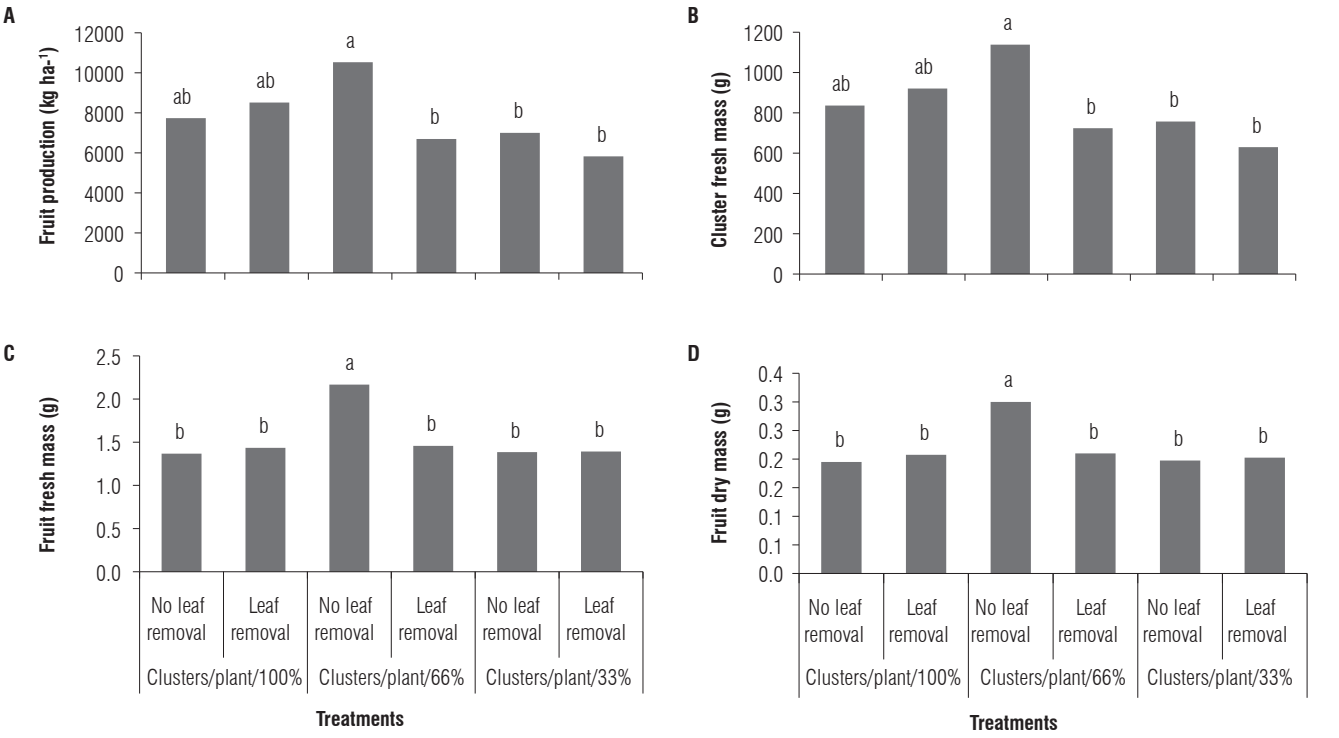


**FIGURE 1.** Effects of leaf removal and cluster thinning, with 33%, 66% or 100% retention of clusters per plant, in Riesling × Silvaner grapevine on: (A) Fruit production per ha; (B) Fresh mass per cluster; (C) Fresh mass per fruit; (D) Dry mass per fruit. Mean values followed by distinct letters are significantly different according to Tukey's test ($P \leq 0.05$).

realized as well as a Tukey test of multiple comparisons on the interactions and the average significant effects ($P \leq 0.05$) by means of the SAS™ program v.8.1e (Cary, NC).

## Results and discussion

### Mass production of fruits and clusters

The fruit production per plant was affected by the intensity of the removal of clusters and leaves. The treatment with 66% clusters and without defoliation showed a significantly highest ($P \leq 0.01$) production (10,530 kg ha$^{-1}$), fresh mass of clusters (1,138.43 g/plant) and fresh and dry mass of the fruit (2.16 g and 0.3 g, respectively) (Fig. 1). Maintaining only 33% of the clusters with leaf removal presented low fresh and dry mass of the fruit, which meant a considerable decrease in the cluster fresh mass and in the entire fruit production of the plant (Fig. 1).

On this matter, Mota *et al.* (2010) found that the thinning of clusters generated a decrease of the cluster weight of 'Merlot' and 'Cabernet Sauvignon' vine grapes. On the contrary, Reynolds *et al.* (1994) reported an increase in the cluster weight, whereas Nuzzo and Matthews (2006) did not find differences.

According to Casierra-Posada *et al.* (2007), the practice of fruit thinning increases size but also reduces the total fruit production; so, it is necessary to strike a balance between production and the size of the fruit (Day *et al.*, 1992). With 66% retention of the fruits per plant a better balance is achieved compared to the other evaluated thinning treatments, since a major response was obtained in production, fresh mass of clusters and fresh and dry mass of the fruit ($P \leq 0.01$). The behavior of these variables was fitted to a quadratic model in function of fruits per plant percentage (Fig. 2).

Consistently, the sink/source ratio can influence the yield of a plant, as well as the size and weight of each of the fruits (Peluzio *et al.*, 1999). After reducing the number of fruits, assimilates targeted for the removed fruits will be attracted by the adjacent remaining fruits (Ho, 1992), increasing weight and size (Russell and Morris, 1983). Nevertheless, in this case, the high sink strength for the photoassimilates can diminish the expansion of the leaves and accelerate ageing, as was found in melon by Valantin *et al.* (1998).

Although a statistically equal production was obtained with 100% of the clusters as compared to retaining 66 % of

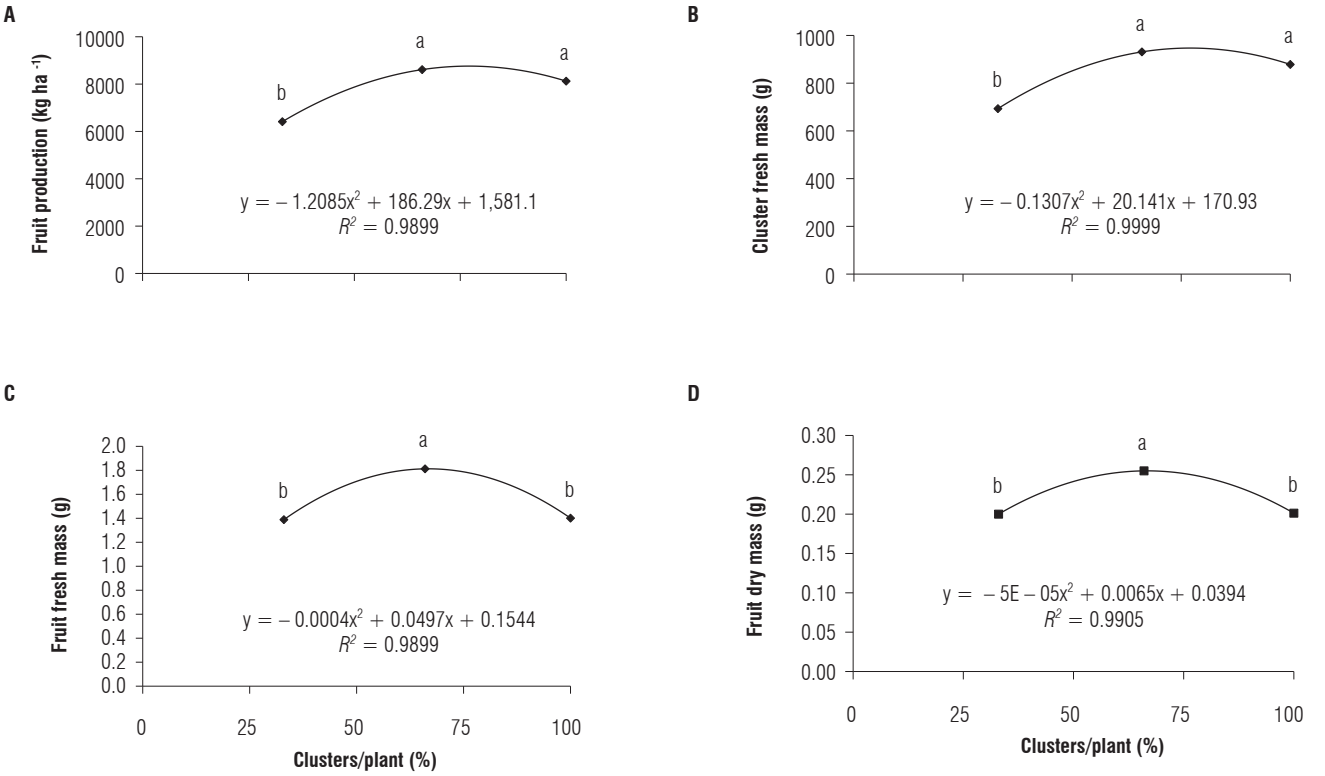


**FIGURE 2.** Effect of cluster thinning, with 33%, 66% or 100% retention of clusters per plant, in Riesling × Silvaner grapevine on: A. Fruit production per ha; B. Fresh mass per cluster; C. Fresh mass per fruit; D. Dry mass per fruit. Mean values followed by distinct letters are significantly different according to Tukey's test ($P \leq 0.05$).

clusters/plant, this high fruit number can negatively affect plant growth and diminish the nutritional reserves for future crops. In fact, an increase in the number of fruits can increase the fraction of photoassimilates assigned to the fruits at the expense of the growth of the vegetative parts (Andriolo and Falcão, 2000). Partially different results were found by Mueller and Wamser (2009) in the tomato with an increase in total fruit production according to the number of trusses, but there was a quadratic decrease in the average mass of marketable fruits as the truss number per plant increased. Similarly, Lavín *et al.* (2001) observed in 'Chardonnay' plants an increase in grape production according to the level of fruit load. In the case of 33% clusters, production was negatively affected due to the low number of clusters; nevertheless, the atypical result was the low weight of clusters and fruits, as the weight was expected to be higher due to the decreased competition between sinks.

With the leaf removal factor, there was a major response of the variables of production ($P \leq 0.05$) without defoliation (Tab. 1), which indicates that a reduction of leaf area can decrease the grape yield, as Scarpare Filho *et al.* (2010) observed in 'Niagara Pink' plants. On the other hand, Bennett *et al.* (2005) report that a decrease of the leaf area can restrict the accumulation of carbohydrates, which generates negative impacts on flowering and yield.

## Grape quality

A high pH was observed in the treatment with 33% clusters and without defoliation ($P \leq 0.01$). The opposite response was observed with 66% clusters and with 60%

**TABLE 1.** Effect of leaf thinning on the production and quality of 'Riesling × Silvaner' (*Vitis vinifera* L.) grapevine.

| Leaf thinning | Grape production (kg ha$^{-1}$) | Cluster fresh weight (g/plant) | Fresh weight (g/berry) | Dry weight (g/berry) | pH | TSS (ºBrix) | TTA (%) | TMI (TSS/TTA) |
|---|---|---|---|---|---|---|---|---|
| Without thinning | 7748.02 a | 910.50 a | 1.64 a | 0.23 a | 3.77 a | 22.47 b | 0.62 b | 36.16 a |
| Thinning (60%) | 6450.42 b | 758.04 b | 1.43 b | 0.21 b | 3.73 b | 22.91 a | 0.69 a | 33.50 b |

Mean values followed by distinct letters are significantly different according to Tukey's test ($P \leq 0.05$).

leaf removal (Fig. 3A). It was found that with increasing the cluster number the pH decreased ($P \leq 0.01$); this behavior was explained by means of a polynomial of the second grade (Fig. 4A). On the other hand, no removal of leaves caused a higher pH value (Tab. 1). These results agree with Franco-Aladren (1996), who found in 'Garnacha' that cluster thinning during the veraison stage provokes a yield loss and moves forward the date of wine grape harvest, also the pH was high, whereas the acidity was reduced. Nevertheless, Mota *et al.* (2010) did not find any significant effect of cluster thinning on the pH.

Partial defoliation removal favored higher juice acidity ($P \leq 0.01$; Tab. 1); the opposite was observed in fruits in the treatments with cluster removal ($P \leq 0.01$; Fig. 4B). Thus, the grapevines with 33% clusters and without leaf removal developed the lowest fruit content of ATT (Fig. 3B), which agrees with the results of Lavín *et al.* (2001) who found a high content of tartaric acid in fruits of vines without fruit thinning and with low levels of fruit thinning.

The decrease in acidity as a result of leaf thinning was probably related to the consumption of malic acid in fruit cell respiration. Valdivia (2001) found that low solar exposure of clusters due to a dense canopy results in lower respiration rates and thus a decreased consumption of organic acids. Nevertheless, many studies have found that the removal of leaves caused decreases of TTA (Mota *et al.*, 2010; Keller *et al.*, 2005; Bucelli and Gianetti, 1996), but other authors did not report significant effects (Campostrini *et al.*, 1991).

The TSS presented statistical differences both for the level of the treatments and the factors. With 66% clusters and without leaf removal the highest TSS content was recorded; on the contrary, retaining only 33% of the clusters and without defoliation the accumulation of TSS was lower (Fig. 3C). This confirms the results of Coombe and McCarthy (2000), who indicate that the increase of sugars is due to the transpiration, which in consequence causes rapid dehydration of the fruit (Almanza-Merchán and Balaguera-López, 2009). Meanwhile, Hunter and Him Roux (1992) found that the concentration of sugar in the 'Cabernet Sauvignon' grape does not change with a reduction in leaf area.

A quadratic equation explained the behavior of TSS according to the intensity of cluster thinning. Maintaining 66% clusters resulted in the highest TSS content (Fig. 4 C). This result agrees with studies of Pszczólkowski *et al.* (1985),

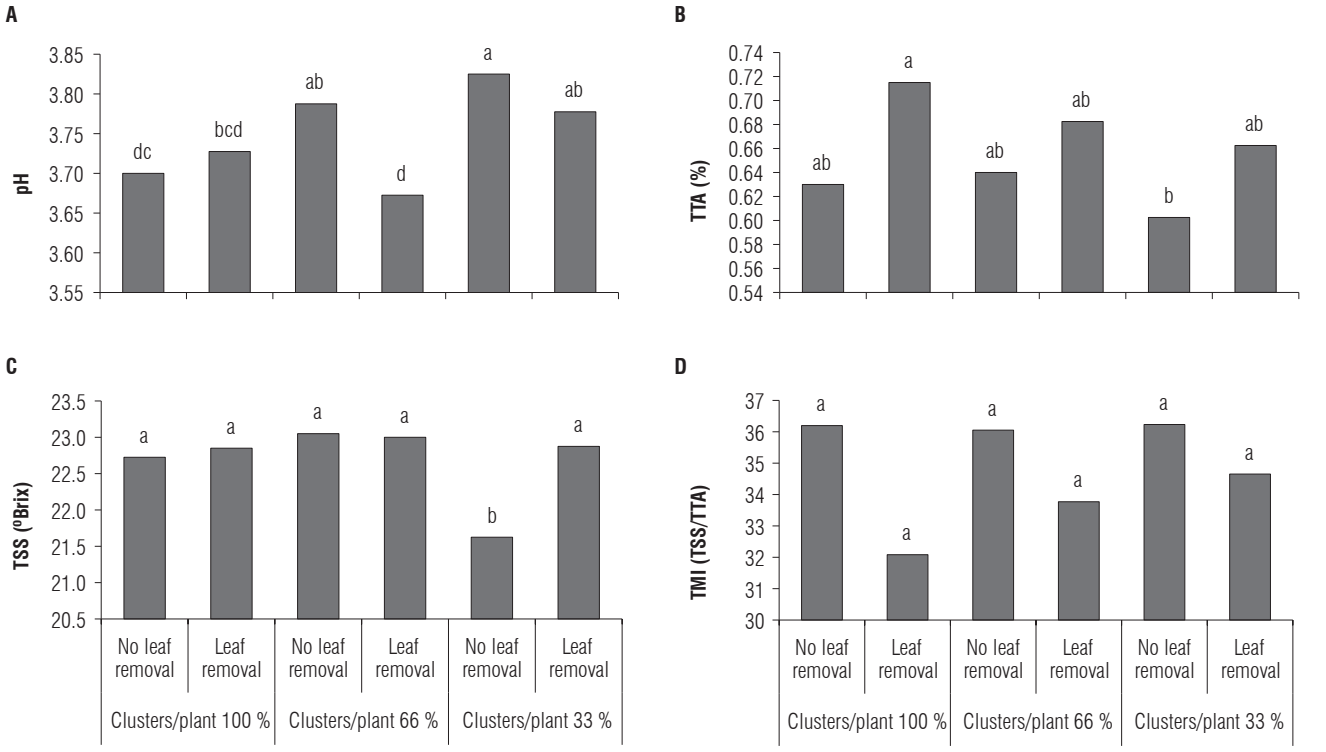


**FIGURE 3.** Effects of leaf removal and cluster thinning, with 33%, 66% or 100% retention of clusters per plant, in 'Riesling × Silvaner' fruits on: A. pH; B. Total tritatable acids (TTA); C. Total soluble solids (TSS); D. Technical maturity index (TMI). Mean values followed by distinct letters are significantly different according to Tukey's test ($P \leq 0.05$).

who affirm that the higher exposure of the clusters to solar radiation stimulates the translocation of photoassimilates towards the fruits, as a result of stimulation by the increase in temperature in the fruit and because in the veraison stage there exists a minor competition among the foliage due to the loss of functionality of the xylem (Coombe and McCarthy, 2000; Rogiers *et al*., 2006).

Casierra-Posada *et al*. (2007) confirm that in the peach a higher number of leaves per fruit increased the content of TSS in the fruits, due to the higher attraction of photoassimilates exhibited by the remaining fruits after the thinning practice. These fruits showed a lower competition among themselves (Ho, 1992), which results in an increase in the SST content, which, possibly, also happened in the studied wine grapes.

Regarding defoliation, 60% foliar removal slightly, but significantly, affected ($P \leq 0.05$) TSS content (Tab. 1). Possibly, due to the fact that the partial leaf removal practice allowed a higher exposure of the fruits to solar radiation which in turn favored the micro-environmental conditions of the clusters and thus improved the quality of the wine grapes, which coincides with the results of Muñoz (2002), nevertheless, it increases the risk of sun scorching the grapes.

In accordance with Gray *et al*. (2010) and Mota *et al*. (2006), the maturity index represents a balance between sugars and acids, important for the wine quality, since this balance favors the wine flavor. Significant differences in the TMI were only found in the leaf removal treatment (Fig. 3D, 4D and Tab. 1). Nevertheless, this practice reduced the TMI because the TTA increased with a higher proportion than the TSS (Tab. 1). Nevertheless, the values obtained with any of the treatments guaranteed the production of quality wines (Falcão *et al*., 2008).

## Conclusions

As an alternative to improve the quality and production of 'Riesling x Silvaner' berries, retaining 66% of the clusters per plant is recommended, because it generated the highest fruit production per area, mass of clusters and fruits, and total solid soluble content, as well as considerable values of total titratable acids and technical maturity index with a low pH value.

While 60% leaf removal the total soluble solids and titratable acidity increased, and the fruit production and fruit and cluster mass decreased.

Plants with 66% clusters developed higher values for production components and quality characteristics such as

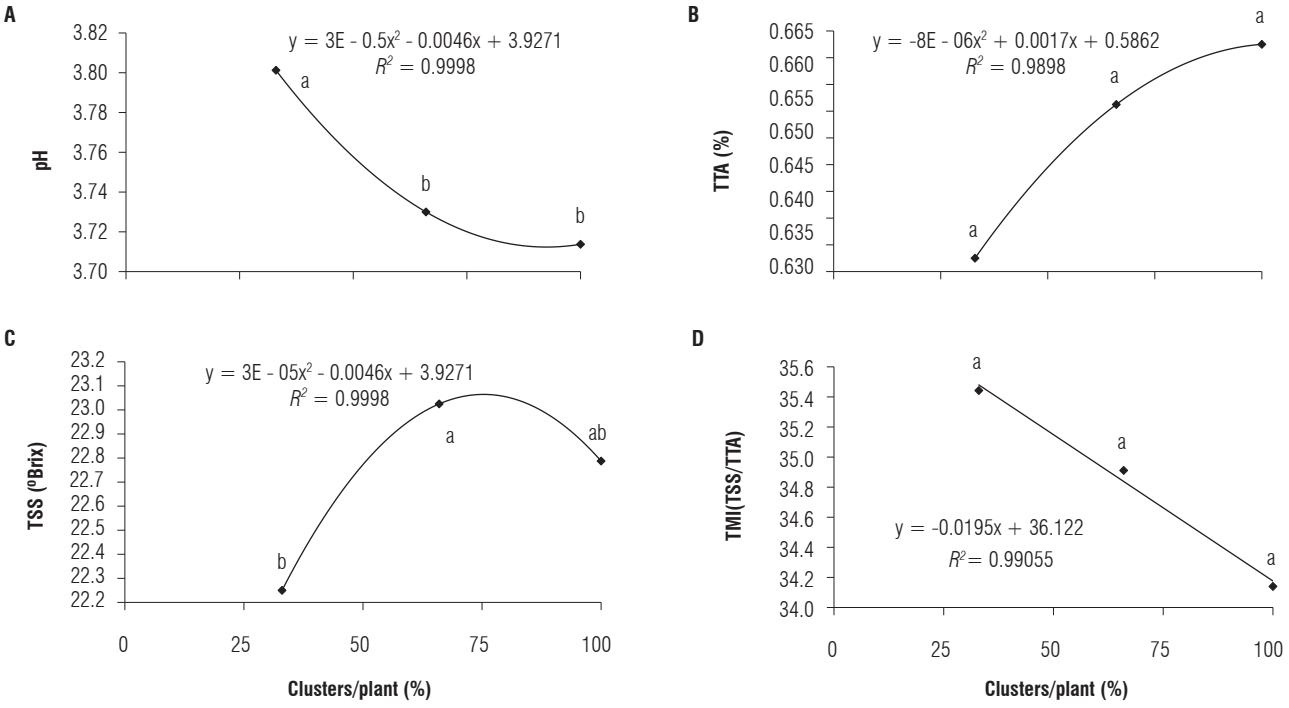


**FIGURE 4.** Effect of cluster thinning, with 33%, 66% or 100% retention of clusters per plant, in 'Riesling x Silvaner' fruits on: A. pH; B. Total tritatable acids (TTA); C. Total soluble solids (TSS); D. Technical maturity index (TMI). Mean values followed by distinct letters are significantly different according to Tukey's test ($P \leq 0.05$).

soluble solids, titratable acidity and technical maturation index, with a low ph in the grapes. Cluster thinning appears to be an alternative to improve the production and quality of grapes for wine making.

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