DOI: 10.5965/223811711722018212

Revista de Ciências Agroveterinárias 17(2): 2018
Universidade do Estado de Santa Catarina

Grape yield and must composition of 'Cabernet Sauvignon' grapevines with organic compost and urea fertilization

Produtividade de uvas e composição do mosto de videiras 'Cabernet Sauvignon' fertilizadas com composto orgânico e ureia

Gustavo Brunetto[1*], Carlos Alberto Ceretta[1], George Wellington Bastos de Melo[2], Alcione Miotto[3], Paulo Ademar Avelar Ferreira[1], Rafael da Rosa Couto[4], Lincon Oliveira Stefanello da Silva[1], Luana Paula Garlet[1], Luiza Michelon Somavilla[1], Adriana Cancian[5] & Vítor Gabriel Ambrosini[5]

[1] Universidade Federal de Santa Maria, Santa Maria, RS, Brasil. [*]Autor para correspondência: brunetto.gustavo@gmail.com.
[2] Empresa Brasileira de Pesquisa Agropecuária, Bento Gonçalves, RS, Brasil.
[3] Instituto Federal de Santa Catarina, São Miguel do Oeste, SC, Brasil.
[4] Instituto Federal Catarinense, Rio do Sul, SC, Brasil.
[5] Universidade Federal do Rio Grande do Sul, Porto Alegre, RS, Brasil.

Submission: 29/01/2017 | Acceptance: 09/05/2018

ABSTRACT

Urea and organic compost are applied as a nitrogen (N) source in vineyards. The aim of this study was to evaluate the yield, total N content in the leaves and the must composition in grapevines with the application of organic compost and urea. 'Cabernet Sauvignon' grapevines, in the 2008/2009 and 2009/2010 crop seasons were subjected to the application of 40 kg N ha^{-1} in the form of organic compost and urea; but there were also unfertilized grapevines. In both crop seasons, leaves were collected at the stages of full flowering and at the change in color of the berries, and the total N content were analyzed; grape yield was evaluated and enological attributes were determined in the must. The application of organic compost and urea did not affect the N content in the leaf nor the grape yield in the second crop season evaluated. However, in the first crop season, grape yield was greater in the grapevines with application of organic compost to the soil. The addition of N sources did not affect the total nutrient content in the must but, in the second crop season, the grape must from the grapevines with the addition of organic compost had a lower soluble solids concentration and a higher total acidity value, as well as tartaric and malic acid values.
KEYWORDS: nitrogen, leaf analysis, *Vitis vinifera* L.

RESUMO

A ureia e o composto orgânico são aplicados em vinhedos como fonte de nitrogênio (N). O estudo objetivou avaliar a produtividade, o teor de N total em folhas e a composição do mosto em videiras submetidas à aplicação de composto orgânico e ureia. Videiras 'Cabernet Sauvignon' nas safras de 2008/2009 e 2009/2010 foram submetidas à aplicação de 40 kg de N ha^{-1} na forma de composto orgânico e ureia, mas videiras também não foram adubadas. Nas duas safras foram coletadas folhas no florescimento e na mudança da cor das bagas, preparadas e submetidas à análise de N total. A produção de uva foi avaliada e atributos enológicos foram determinados no mosto. A aplicação de composto orgânico e ureia não afetou o teor de N total nas folhas e a produção de uva na segunda safra avaliada. Mas, na primeira safra, a produção de uva foi maior nas videiras submetidas à aplicação com composto orgânico no solo. A adição de fontes de N não afetou o conteúdo de nutrientes no mosto mas, na segunda safra, o mosto da uva derivado das plantas com a adição de composto orgânico apresentou baixo teor de sólidos solúveis totais, maior valor de acidez, ácido tartárico e ácido málico.
PALAVRAS-CHAVE: nitrogênio, análise foliar, *Vitis vinifera* L.

INTRODUCTION

In the Serra Gaúcha region, located in the northeast of the state of Rio Grande do Sul, RS, Brazil, vineyards are normally planted in clayey soils with medium organic matter content, which provides them with good nitrogen (N) availability. However, the amounts may be insufficient to supply grapevine demand for the nutrient. For that reason, nitrogen fertilizers, such as urea, should be distributed on the vineyard soil surface in one or two applications, as of the beginning of bud break of the plants (CQFS-RS/SC 2004). However, studies have shown that grapevines grown in clayey soils with medium organic matter content normally utilize a small quantity of the N derived from the urea (BRUNETTO et al. 2008). This occurs because, in the soil, the action of the extracellular urease enzymes causes rapid hydrolysis of the urea [$(NH_2)_2CO$] with subsequent formation of ammonia (NH_3-N), which is partially lost through volatilization, and of nitrate (NO_3-N), formed in the nitrification process, which is easily transferred to the environment through leaching and surface runoff (BARLOW et al. 2009, LORENSINI et al. 2012).

Thus, to minimize N transfers, organic sources of the nutrient have been used, such as organic compost, which may be generated by the aerobic composting of organic residues. With the application of organic compost on the soil surface, without incorporation, there is less contact with the soil, which limits the action of decomposer organisms and, consequently, the N mineralization rate. Some studies have shown that this practice can minimize NH_3-N volatilization and NO_3-N transfer through leaching and surface runoff, in comparison to the use of urea (LORENSINI et al. 2012). In addition to lower transfers, the lower mineralization rate probably improves the synchronism between N release and its uptake by the grapevines (MELO et al. 2012, LORENSINI et al. 2014).

However, little is known about the effect of application of organic compost on the nutritional state of the grapevines in comparison to urea, which may be estimated by the total N content in the whole leaf (BRUNETTO et al. 2006). Moreover, the effect of application of N sources in regard to grape yield and its components is not known, such as cluster weight and 100-berry weight (BRUNETTO et al. 2007, 2008), nor is it known in regard to must composition indicators, among which is total nutrient content and, within it, N content, which is a determining factor for must fermentation (BELTRAN et al. 2005, MARTÍ-RAGA et al. 2015). Must quality may also be evaluated by the soluble solids values which, when in the ºBrix scale, represents 90% of the sugars found in the must, pH, total acidity and tartaric and malic acid, which represent more than 90% of the total acids of the berry and indicate the stability and longevity of the wine (KELLER et al. 1999, FERNANDES et al. 2015, VARGAS et al. 2016). The aim of this study was to evaluate the effect of application of organic compost and urea on yield, total N content in the leaves and grape must composition.

MATERIALS AND METHODS

The experiment was conducted in a vineyard in Bento Gonçalves in the Serra Gaúcha region of RS, Brazil. The vineyard consists of Cabernet Sauvignon cultivar grafted on the SO4 rootstock, planted in 1986 with a density of 2,666 plants per hectare (1.5 x 2.5 m) andtrained on a horizontal overhead trellis system. Climate in the region, according to the Köppen classification, is of the Cfa subtropical type. The values of rainfall and temperature throughout the period of the experiment are shown in Figure 1. The soil type was Udor thent and, in the 0-20 cm layer before setting up the experiment, it exhibited the following attributes: clay - 240 g kg^{-1}; organic matter - 27.0 g kg^{-1}; pH in water - 6.3; exchangeable Al - 0.0 $cmol_c$ dm^{-3}; exchangeable Ca - 8.8 $cmol_c$ dm^{-3}; exchangeable Mg - 3.3 $cmol_c$ dm^{-3} (1 mol L^{-1} KCl extractor); available P - 18.9 mg dm^{-3} and exchangeable K - 0.5 $cmol_c$ dm^{-3} (Mehlich 1 extractor), and $CEC_{pH7.0}$ of 9.2 $cmol_c$ dm^{-3}.

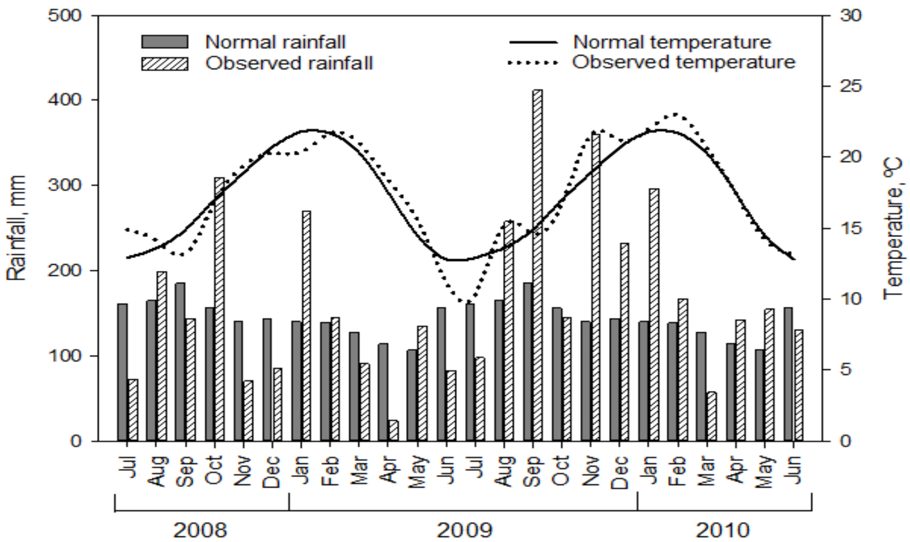

Figure 1. Rainfall and temperature in the experimental area in the 2008/2009 and 2009/2010 crop seasons.

The grapevines were subjected to the application of 40 kg N ha^{-1} $year^{-1}$ in the form of organic compost (with the following characteristics: dry matter – 841 g kg^{-1}; pH in water - 9.6; NO_3-N - 4.0 g kg^{-1}; NH_4^+-N - 4.6 g kg^{-1}; total N - 19.0 g kg^{-1}; total P - 17.3 g kg^{-1}; total K – 32 g kg^{-1}; total Ca – 25 g kg^{-1}; total Mg - 2.0 g kg^{-1} and total organic carbon - 199.0 g kg^{-1}) and 40 kg N ha^{-1} $year^{-1}$ in the form of urea (45% N), plus a control treatment without fertilization. Nitrogen, in the form of compost and urea, was applied in a single dose in August 2008 and 2009, at bud burst of the grapevines. Nitrogen sources were applied manually to the soil surface, without incorporation, and in 0.5 m wide strips in the plant row.Throughout the grapevine cycle, weeds were controlled with applications of glyphosate herbicide in the strip where the N was applied and between the rows, weeds were controlled by means of mowing. In winter pruning a mixed method was used, maintaining equivalence in the number of buds per plant. A randomized block experimental design was used with five replications, with each plot consisting of five plants, where evaluations were made on the three center plants on an annual basis.

In the month of October, during full flowering of the grapevines, and in the month of January, at the change in color of the berries, in the 2008/2009 and 2009/2010 crop seasons, 15 mature leaves per plant were collected from both sides of the plant row. The leaves were then dried in a laboratory oven at 65 ºC until constant weight, ground in a Wiley knife mill and subjected to analysis of total N content by the Kjeldahl method (TEDESCO et al. 1995). In March 2009 and 2010, at maturity of the berries, all the clusters from each plant were collected and their mass was determined by means of a digital balance. Soon after, five clusters per plant were selected, from which 100 grape berries were removed from the upper, middle and lower part, and their mass was determined by means of a digital balance. The collected berries were then divided into two portions for determination of the N, P and K contents and other attributes of the must. In the first portion, 30 berries were ground in a blender and a subsample of the must was collected and subjected to analysis of total N, P and K (TEDESCO et al. 1995). The remaining berries were macerated and, in the must obtained, the following values were determined: pH, using a digital potentiometer; soluble solids, using a digital bench to refractometer with temperature control; acidity by titration with 0.1 mol L^{-1} NaOH; and malic and tartaric acid by high performance liquid chromatography. However, in the 2009/2010 crop season, the tartaric and malic acid contents in the grape must were not analyzed. The results obtained were subjected to analysis of variance using the Sisvar statistical program and, when the effects were significant, the mean values were compared by the Scott-Knott test (α=0.05).

RESULTS AND DISCUSSION

Total nitrogen content in the whole leaf

The total N content in whole leaves collected at full flowering and at change in color of the berries in the 2008/2009 and 2009/2010 crop seasons was not affected by the application of organic compost and urea on the soil surface (Table 1), agreeing with the results obtained by CASALI et al. (2015) with 'Niágara Rosada' grapevines in the same region. Based on these results, it may be inferred that even in the soil without fertilization, which had 27.0 g kg^{-1} of organic matter, considered as medium (26-50 g kg^{-1}) (CQFS-RS/SC 2004), there is the release of satisfactory quantities of N derived from the mineralization process. This process is maintained by the contribution of plant residues, such as decaying leaves, pruned branches, the above ground part of weeds, and also biological fixation carried out by native leguminous species or species planted in the vineyards (PATRICK et al. 2004). The importance of these plants grown between the rows of the vineyards is reported in various studies because they promote increased availability of nutrients in the soil, especially N, and their uptake by grapevines (BRUNETTO et al. 2009, 2011). Due to these processes, the total N contents in the leaves of the grapevines of the treatment without fertilization (but also in those subjected to the application of organic compost and urea) collected at full flowering were considered as above normal (>24.0 g kg^{-1}), and at the change in color of the berries, as normal (16.0-24.0 g kg^{-1}) (CQFS-RS/SC 2004). It is fitting to highlight that for both the crop seasons evaluated, rainfall in the months of August, September and October was above normal (Figure 1), which favored good soil moisture levels and, consequently, biological activity and mineralization of organic matter. On the other hand, excessive rain may have increased N losses by leaching and by surface runoff (LORENSINI et al. 2012).

Grape yield and its components

In the 2008/2009 crop season, the greatest grape yield per plant and hectare was observed in the grapevines subjected to the application of organic compost on the soil surface (Table 1). In contrast, grape yield of the grapevines with the addition of urea was the same as that observed in the grapevines without fertilization. The greater grape yield in the grapevines with the application of organic compost may be attributed to the tendency of greater 100-berry weight (Table 1), but it may also be explained by the greater

Table 1. Total nitrogen content in whole leaves collected at full flowering and at change in the color of berries, grape yield per plant and hectare, number of clusters per plant, average weight of the clusters and average 100-berry weight in ‘Cabernet Sauvignon’ grapevines with the application of organic compost and urea.

Source of nitrogen	Crop Season	
	2008/2009	2009/2010
---------------------- Total N in the leaves collected at full flowering (g kg^{-1}) ----------------------		
Control	38.0 a[(1)]	35.6 ns
Organic compost	37.1 a	35.6
Urea	30.3 c	32.9
------------- Total N in the leaves collected at change in color of the berries (g kg^{-1}) -------------		
Control	23.9 ns	22.4 ns
Organic compost	21.5	22.3
Urea	23.4	21.5
-- Grape yield per plant (kg^{-1}) --------------------------------------		
Control	3.17 b	0.62 ns
Organic compost	7.79 a	0.56
Urea	3.14 b	0.78
----------------------------------- Grape yield per hectare (Mg ha^{-1}) -----------------------------------		
Control	8.46 b	1.65 ns
Organic compost	20.78 a	1.50
Urea	8.38 b	2.10
----------------------------- Average weight of the clusters per $plant^{-1}$ (g) -----------------------------		
Control	133.20 ns	57.81 ns
Organic compost	101.00	42.33
Urea	101.00	56.40
-------------------------------------- Average 100-berry weight (g) --------------------------------------		
Control	131.90 ns	94.17 ns
Organic compost	141.71	109.67
Urea	129.36	94.00

(1)Mean values followed by the same letter in the column do not differ among themselves by the Scott-Knott test (α=0.05).

number of clusters per plant, as observed by BRUNETTO et al. (2009) in another ‘Cabernet Sauvignon’ vineyard with application of doses of N in the form of urea in an Udorthent soil, near the experimental vineyard of the present study. Nevertheless, this variable was not evaluated in the present study. But, in addition, greater grape yield may have occurred because organic compost has a small area of contact with the soil surface, which prolongs the release and availability of forms of N in the vineyard soil (MELO et al. 2012, LORENSINI et al. 2014) and, therefore, one may expect that the grapevine utilizes a greater quantity of the N derived from the organic compost. Nevertheless, it is fitting to report that in this 2008/2009 crop season, the lower release of N from the compost to the soil may have occurred because of the lower volume of rainfall (Figure 1) and, consequently and possibly, of soil moisture, especially in the months after its application up to grape harvest, with the exception of the months of October 2008 and January 2009, in NH_3-N through the volatilization which occurs in greater intensity soon after its application on the soil surface (LORENSINI et al. 2012). According to these authors, in a study undertaken in the Campanha Gaúcha region,over 80 hours after application of 40 kg N ha^{-1} in the form of urea, the accumulated losses through volatilization of NH_3-N were 5.51 kg N ha^{-1}, greater than the 0.35 kg N ha^{-1} observed in the treatment with application of the same quantity of N in the form of organic compost.

Table 2. Total content of nitrogen, phosphorus and potassium, soluble solids, pH, total acidity, tartaric and malic acid in grape must in 'Cabernet Sauvignon' grapevines with the application of organic compost and urea.

Source of nitrogen	Crop Season	
	2008/2009	2009/2010
---------- Nitrogen content in the must (%) ----------		
Control	0.09 ns	0.72 ns
Organic compost	0.10	0.68
Urea	0.11	0.63
---------- Total phosphorus in the must (%) ----------		
Control	0.01 ns	0.17 ns
Organic compost	0.01	0.24
Urea	0.02	0.23
---------- Total potassium in the must (%) ----------		
Control	0.29 ns	0.11 ns
Organic compost	0.30	0.12
Urea	0.27	0.14
---------- pH ----------		
Control	3.71 ns	3.82 b
Organic compost	3.74	3.49 c
Urea	3.75	3.98 a
---------- Total acidity (meq L^{-1}) ----------		
Control	80.47 ns	64.82 b(1)
Organic compost	80.06	82.06 a
Urea	86.15	51.32 b
---------- Soluble solids (ºBrix) ----------		
Control	17.60 ns	18.02 a
Organic compost	18.93	15.52 b
Urea	18.23	18.20 a
---------- Tartaric acid (g L^{-1}) ----------		
Control	3.38 ns	5.03 b
Organic compost	3.72	5.54 a
Urea	3.66	4.49 b
---------- Malic acid (g L^{-1}) ----------		
Control	4.76 ns	4.43 b
Organic compost	4.56	4.93 a
Urea	5.52	4.10 b

(1)Mean values followed by the same letter in the column do not differ among themselves by the Scott-Knott test (α=0.05).

In the 2009/2010 crop season, the application of organic compost and urea did not affect grape yield per plant and hectare (Table 1). This may probably be attributed to the greater volume of rainfall in comparison to the 2008/2009 crop season in most of the months after the application of the organic compost and urea on the soil surface (Figure 1). Therefore, there may have been greater transfer of forms of N by leaching, especially nitrate (NO_3^--N), but especially by the soil surface runoff solution (BARLOW et al. 2009, LORENSINI et al. 2012). Nevertheless, it is fitting to emphasize that the greater rainfall volume in the 2009/2010 crop season may also have increased the incidence of fungal disease in the above ground part of the grapevines, reducing the fertile flowers (BRUNETTO et al. 2009), which, consequently, may decrease grape yield, which was less than that obtained in the 2008/2009 crop season. All this may have had an impact on the effect of application of organic compost and of urea on grape yield. It is also fitting to emphasize that in the two crop seasons evaluated, the application of organic compost and of urea on the soil did not affect the mean weight of the clusters or the 100-berry weight.

Must composition

In the 2008/2009 and 2009/2010 crop seasons, the application of organic compost and urea did not affect the total N, P and K contents in the must of the berries of the wine-producing ‘Cabernet Sauvignon’ grapevines (Table 2). The results of the total N and P contents are in agreement with those obtained by BRUNETTO et al. (2009), also in ‘Cabernet Sauvignon’ grapevines with the application of urea in the Serra Gaúcha region of RS.

In the 2008/2009 crop season, the application of organic compost and urea did not have an effect on the values of pH, total acidity, soluble solids, tartaric acid and malic acid in the must (Table 2), agreeing with the results obtained by MELO et al. (2012), who applied organic compost on the soil surface in grapevines grown in the Serra Gaúcha region of RS, and did not observe an effect on the values of these same attributes. In contrast, in the 2009/2010 crop season, the greatest values of pH were observed in the must derived from the grapevines with the application of urea, which agrees with the data reported by BRUNETTO et al. (2009). Greater values of total acidity, tartaric acid and malic acid, for their part, were observed in the must of the grapevines with the application of organic compost, especially the values of tartaric and malic acid, which may indicate greater stability and longevity of the wine; in addition, the values of total acidity and of the acids may probably be explained by the greater vegetative growth of the above ground part of the grapevines in comparison to those with the addition of urea and without fertilization, which increases the shading of the clusters in the inner part of the plants, retarding grape maturation and the degradation of organic acids in the berry (KELLER et al. 1999). The grapevines with the application of urea and without fertilization exhibited equal values of all the parameters evaluated in the must in both years (Table 2). The lower values of soluble solids in the must may be the result of a lower dilution, explained by the tendency (since there was no statistical difference) of greater 100-berry weight of the grapes produced on the grapevines with the use of organic compost (Table 1). Smaller berries have a lower pulp/peel ratio and, consequently, there is greater concentration of important compounds responsible for coloring of the must and of the wine, but also of sugars (KELLER et al. 1999).

CONCLUSION

The application of organic compost and urea on grapevines grown in a soil with medium organic matter content did not affect the N content in the whole leaf nor grape yield in the second crop season evaluated. However, in the first crop season, grape yield was greater in the grapevines with the application of organic compost on the soil. The nitrogen sources did not affect the nitrogen, phosphorus and potassium content of the must but, in the second crop season, although the quantity of total soluble solids was less, the values of total acidity, tartaric and malic acid were greater in the must of the grapevines with the application of organic compost.

ACKNOWLEDGEMENTS

To the FAPERGS, to the CNPq and to Capes (Public Notice 034/2007), for the scholarships granted and the financial resources made available. The first and second authors thank the CNPq for research grants.

REFERENCES

BARLOW K et al. 2009. Nitrogen concentrations in soil solution and surface run-off on irrigated vineyards in Australia. Australian Journal of Grape and Wine Research 15: 131-143.

BELTRAN G et al. 2005. Influence of the timing of nitrogen additions during synthetic grape must fermentations on fermentation kinetics and nitrogen consumption. Journal of Agricultural and Food Chemistry 53: 996-1002.

BRUNETTO G et al. 2006. Recuperação e distribuição do nitrogênio fornecido a videiras jovens. Pesquisa Agropecuária

Brasileira 41: 1299-1304.

BRUNETTO G et al. 2007. Aplicação de nitrogênio em videiras na Campanha Gaúcha: produtividade e características químicas do mosto da uva. Ciência Rural 37: 389-393.

BRUNETTO G et al. 2008. Produção, composição da uva e teores de nitrogênio na folha e no pecíolo em videiras submetidas à adubação nitrogenada. Ciência Rural 38: 2622-2625.

BRUNETTO G et al. 2009. Produção e composição química da uva de videiras Cabernet Sauvignon submetidas à adubação nitrogenada. Ciência Rural 39: 2035-2041.

BRUNETTO G et al. 2011. Nutrient release during the decomposition of mowed perennial ryegrass and white clover and its contribution to nitrogen nutrition of grapevine. Nutrient Cycling in Agroecosystems 3: 299-308.

CASALI AV et al. 2015. Estado nutricional, produção e composição das uvas de 'Niágara Rosada' submetidas à aplicação de composto orgânico. Revista de Ciências Agrárias 58: 257-262.

CQFS-RS/SC. 2004. Comissão de Química e Fertilidade do Solo. Manual de adubação e calagem para os Estados do Rio Grande do Sul e de Santa Catarina. Porto Alegre: SBCS. 400p.

FERNANDES AM et al. 2015. Brix, pH and anthocyanin content determination in whole Port wine grape berries by hyperspectral imaging and neural networks. Computers and Electronics in Agriculture 115: 88-96.

LORENSINI F et al. 2012. Lixiviação e volatilização de nitrogênio em um Argissolo cultivado com videira submetida à adubação nitrogenada. Ciência Rural 42: 1173-1179.

LORENSINI F et al. 2014. Disponibilidade de nitrogênio de fontes minerais e orgânicas aplicadas em um Argissolo cultivado com videira. Revista Ceres 61: 241-247.

KELLER M et al. 1999. Excessive nitrogen supply and shoot trimming can impair colour development in Pinot Noir grapes and wine. Australian Journal of Grape and Wine Research 5: 45-55.

MARTÍ-RAGA M et al. 2015. The effect of nitrogen addition on the fermentative performance during sparkling wine production. Food Research International 67: 126-135.

MELO GWB et al. 2012. Resposta das videiras a diferentes modos de distribuição de composto orgânico no solo. Revista Brasileira de Fruticultura 34: 493-503.

PATRICK AE et al. 2004. Grapevine uptake of ^{15}N-labeled nitrogen derived from a winter-annual leguminous cover-crop mix. American Journal of Enology and Viticulture 55: 187-190.

TEDESCO MJ et al. 1995. Análises de solo, plantas e outros materiais. 2.ed. Porto Alegre: UFRGS. 174p.

VARGAS E et al. 2016. Automatic bionalyzer using an integrated amperometric biosensor for the determination of L-malic acid in wines. Talanta 158: 6-13.