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Photosynthesis and growth of young "Niágara Branca" vines (*Vitis labrusca L.*) cultivated in soil with high levels of copper and liming

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Abstract. The objective of this study was to evaluate the photosynthetic response and growth of young grape "Niagara Branca" vines grown in soil with high content of Cu and liming. The experiment was conducted in controlled environment with soil subjected to three levels of liming, with 0, 1.5 and 3.0 Mg ha^{-1} of lime. The effect of additional 50 mg kg^{-1} Cu in half of soil treatments was evaluated. The CO_2 measurements, assimilation rate, stomatal conductance and transpiration were carried out in the tenth cultivation week using the IRGA equipment (Infrared Gaz Analyzer). Plant height, fresh weight and dry weight, concentration of chlorophyll a, chlorophyll b, total chlorophyll, and carotenoids were measured. For most variables, the Cu had damaging effect on 0 and 1.5 Mg ha^{-1} liming treatments however, there was no significant damage in the 3.0 Mg ha^{-1} treatment. Rates of CO_2 assimilation, stomatal conductance, and transpiration were increased with the addition of 50 mg kg^{-1} Cu. Liming to raise the pH of the soil is an effective practice to reduce the effects of Cu toxicity in young "Niagara Branca" grape vines.

1. Introduction

Young "Niagara Branca" grape vines (*Vitis labrusca*) are routinely subjected to successive applications of fungicides and copper (Cu)-based Bordeux mixture for preventive control of foliar fungal diseases. Residual Cu can accumulate in soils after continuous application, increasing the available form of the element [3,5].

Cu is an essential to the growth and development of plants micronutrient, but when the soil contains high concentrations, the amount absorbed by plants can be excessive and cause decreased concentrations of photosynthetic pigments, such as chlorophyll and carotenoids, which are responsible for the conversion of light into chemical energy in the form of NADPH and ATP with the releasing O_2 [4]. However, impairment of the photosynthetic efficiency of plants results in reduced growth. Therefore, analysis of Cu concentrations becomes a necessary strategy to mitigate the toxic effects of Cu to young vines.

When the pH of the soil is low, Cu forms are available in greater amounts in soil [1] and therefore, the use of lime for its repair may be an important tool to reduce the availability of the element in the soil, and hence its uptake by plants. Therefore, the application of lime to raise the pH can be an important strategy to reduce the toxicity of Cu to plants.

The study aimed to evaluate the photosynthetic response and growth of young "Niágara Banca" vines, grown in soil with high content of Cu and liming levels.

2. Materials and methods

The experiment was conducted at Federal University of Santa Catarina-SC, in a controlled environment room at $25 \pm 2\,^{\circ}$C with a 16 h light day^{-1} photoperiod with photosynthetically active radiation of 200 μmol photon m^2 s^{-1} $\pm$ 10 using seedlings produced by *in vitro* propagation, after about 60 days of acclimatization. The

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Table 1. Fresh weight and dry weight (g) of shoots of "Niágara Branca" seedlings grown in soil with different levels of lime and copper concentrations.

	Fresh weigth of aerial			Dry weigth of aerial		
	Cu 0	Cu 50	Average	Cu 0	Cu 50	Average
Liming 1	6,04 aA	4,00 bB	5,02 b	2,14 aA	1,48 bB	1,81 b
Liming 2	6,53 aA	4,61 bB	5,57 ab	2,35 aA	1,69 bAB	2,02 ab
Liming 3	6,34 aA	5,93 aA	6,13 a	2,15 aA	1,95 aA	2,05 a
Average	6,30 A	4,85 B		2,21 A	1,71 B	
CV(%)		11,33			11,58	

Means followed by different lowercase letters in the column differ by Tukey test at 5% probability of error for the liming factor. Means followed by different capital letters in the line differ by Tukey test (5%) for Cu factor.

soil 0–20 cm from the border was not subjected to anthropic application. Then, lime was applied at doses of 0, 1.5 and 3.0 Mg ha^{-1} to obtain the values of pH 5.2; 6.0 and 7.0, with lime termed 1, 2 and 3 respectively. Limestone ($MgCO_3$ and $CaCO_3$) PA (PRNT 100%), Ca:Mg of 2:1 was used. After incubation of the soil, the pH of the treatment was 4.5; 5.5 and 6.2. Half of the soil received 50 mg kg^{-1} Cu. The experimental design was a randomized block design with six replications in a 3×2 factorial. Each experimental unit consisted of an allocated plant in a "rhizobox" vessel containing 1.2 kg of plant soil.

CO_2 measurements, assimilation rate, stomatal conductance and transpiration were carried out in the tenth cultivation week in time from 10 to 12 using the IRGA equipment (Infrared Gaz Analyzer) model Li-6140XT under a closed system with 380 ppm CO_2 and photosynthetic active radiation of 1000 μmol photon $m^2 s^{-1}$ and leaf area of 6 cm^2. The plant height was measured using a ruler.

At the end of the experiment, the plants were segmented, weighed and dried at 65 °C until constant mass and shoot biomass was determined with a precision balance. The concentration of chlorophyll a, b, total and carotenoid was determined by the dimethylsulfoxide (DMSO) method, using 100 mg of foliar tissue and incubated in a water bath with 7 mL DMSO at 65 °C for two hours without maceration. After filtering, the total volume was adjusted to 10 mL. The values obtained by spectrometry were used in equations Wellburn (1994) being data expressed in μ g mL: chlorophyll a = [12.19*(A665)−3.45*(A649)]; chlorophyll b = [21,99*(A649)−5.32*(A665)]. The total chlorophyll content was determined from the sum of Chl a and Chl b. The content of carotenoids was estimated from the formula: total carotenoids = [1.000*(A480)−2.14*(Chla) −70.16*(Chlb)] / 220.

3. Results and discussion

The fresh weight and dry weight of shoots were reduced with the increase of Cu in soil, with the exception of plants grown in soil with addition of 3.0 Mg ha^{-1} of lime (Table 1). With this level of liming biomass production of 50 Cu treatment increased significantly and did not differ significantly from the treatments without added Cu. For treatments without the addition of copper, liming factor was not significant. (Table 1). For both treatments, the percentage of dry mass was 35% of the fresh weight.

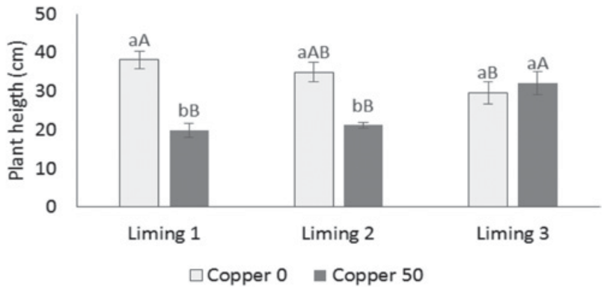

Figure 1. Height (cm) of "Niágara Branca" seedling grown in soil with different levels of lime and copper concentrations. Means followed by the same capital letters factor for copper within the liming factor and lowercase to liming factor in the factor copper do not differ by Tukey test (5%).

The increment in height (Fig. 1), chlorophyll (Tables 2 e 3) and carotenoids (Table 3) of the plants did not differ between the levels of liming for Cu 0. However, for the Cu 50 liming factor was significant for limeing of 0 and 1.5 Mg ha^{-1} Cu addition impaired growth and the concentration of the foliar plant pigments. For the liming, of 3 Mg ha^{-1} average equaled factor for Cu.

Alteration in biomass in height increment and in levels of leaf pigments caused by liming may be a consequence of the reduced availability of Cu by increasing the pH of the soil [1]. Furthermore, the increase of calcium and magnesium in the soil by the addition of lime may have been beneficial for young vines because there is a competition for the absorption of these elements and Cu by plant roots, thereby reducing the content of the trace element in the tissues vegetables [6].

Chlorophyll *a* was more abundant than chlorophyll *b* for all treatments (Table 2). The relation chlorophyll *a*/*b* showed an average standard of 2.5, which is consistent with the values and proportions found by [2] who worked with young "Cabernet Sauvignon" grape vines.

The variable content of carotenoids had no effect on the interaction between factors, but it was found that the addition of Cu reduced its concentration in the leaves of young vines (Table 3).

The rate of CO_2 assimilation, stomatal conductance and transpiration behaved similarly to each other, and there was superiority of fees for treatments with the addition of Cu and no difference for the liming factor in both cases (Tables 4 and 5) . The reduction in leaf area with addition of copper caused an increase in photosynthetic activity. This effect is possibly related to offset the reduction in

Table 2. Chlorophyll *a*, chlorophyll *b* of "Niágara Branca" seedlings grown in soil with different levels of lime and copper concentrations (mg g^{-1}).

	Chlorophyll $a*$			**Chlorophyll** $b*$		
	Cu 0	Cu 50	Average	Cu 0	Cu 50	Average
Liming 1	1,39 aA	1,00 bB	1,20 ab	0,50 aB	0,39 bA	0,45 a
Liming 2	1,36 aA	0,82 bB	1,09 b	0,63 aA	0,39 bA	0,51 a
Liming 3	1,31 aA	1,24 aA	1,28 a	0,49 aB	0,49 aA	0,49 a
Average	1,35 A	1,02B		0,54 A	0,42 B	
CV(%)		10,96			16,73	

Means followed by different lowercase letters in the column differ by Tukey test at 5% probability of error for the liming factor. Means followed by different capital letters in the line differ for Cu factor.

Table 3. Total chlorophyll and carotenoids of "Niágara Branca" seedlings grown in soil with different levels of lime and copper concentrations (mg g^{-1}).

	Total chlorophyll*			**Carotenoids**		
	Cu 0	Cu 50	Average	Cu 0	Cu 50	Average
Liming 1	1,89 aA	1,39 bB	1,64 a	0,24	0,19	0,21 a
Liming 2	1,99 aA	1,21 bB	1,60 a	0,18	0,15	0,16 b
Liming 3	1,81 aA	1,73 aA	1,77 a	0,22	0,2	0,21 a
Average	1,90 A	1,45 B		0,21 A	0,18 B	
CV(%)		10,06			13,8	

Means followed by different lowercase letters in the column differ by Tukey test at 5% probability of error for the liming factor. Means followed by different capital letters in the line differ for Cu factor.

Table 4. CO_2 assimilation rate and stomatal conductance (μ mol m^2 s^{-1}) of "Niágara Branca" seedlings grown in soil with different levels of lime and copper concentrations.

	CO_2 assimilation rate			**Stomatal conductance**		
	Cu 0	Cu 50	Average	Cu 0	Cu 50	Average
Liming 1	5,3 Ba	7,2 Aab	6,2 a	0,00359 Ba	0,00525 Ab	0,00442 a
Liming 2	6,6 Aa	5,4 Ab	6,0 a	0,00413 Aa	0,00365 Aab	0,00389 a
Liming 3	5,8 Ba	8,6 Aa	7,2 a	0,00311 Ba	0,00633 Aa	0,00472 a
Average	5,9 B	7,1 A		0,00361 B	0,00507 A	
CV (%)		20,61			25,97	

Means followed by different lowercase letters in the column differ by Tukey test at 5% probability of error for the liming factor. Means followed by different capital letters in the line differ for Cu factor.

Table 5. Transpiration rate (μ mol m^2 s^{-1}) "Niágara Branca" seedlings grown in soil with different levels of lime and copper concentrations.

	Transpiration rate		
	Cu 0	Cu 50	Average
Liming 1	0,142 Ba	0,238 Aa	0,190 a
Liming 2	0,189 Aa	0,153 Ab	0,171 a
Liming 3	0,137 Ba	0,288 Aa	0,212 a
Average	0,156 B	0,226 A	
CV (%)		26,56	

Means followed by different lowercase letters in the column differ by Tukey test at 5% probability of error for the liming factor. Means followed by different capital letters in the line differ for Cu factor.

leaf area, a result of lower seedling development. Similar effects were observed by several authors [9,10] to evaluate the behaviour of plants at different levels of defoliation. These authors suggest that in plants with leaf restriction, the photosynthetic rate is stimulated in organs due to a situation of stress, resulting in increased redistribution of assimilates. This effect is known as photosynthesis offset [10]. Furthermore, increasing the number of stomata which would allow an increase in gas exchange can occur, but this variable was not assessed.

4. Conclusion

The high Cu contamination in the soil causes harmful effects of the vine physiology. Liming to raise the pH of the soil is an effective practice to reduce the effects of Cu toxicity in young "Niágara Branca" vines, coming to neutralize the toxic effect with the application of 3.0 Mg ha^{-1} for the case study.

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