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STRATEGIES TO INCREASE RED COLOR AND REDUCE THE INCIDENCE OF SUNBURNS ON APPLES

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ABSTRACT - The aim of this study was to evaluate the application of $CaCO_3$ in liquid formulation on the incidence of sunburn and the visual quality of apples, as well as to test application times and dosages of biostimulants in increasing the red Color of the fruits. The study was carried out in partnership with the rural producer, in the orchards located in the municipality of Fraiburgo-SC, in the 2018/2019 harvest. To meet the proposed objectives, two different experiments were conducted: experiment 1 - application of calcium carbonate to reduce the incidence of sunburn in apples and experiment 2 - use of biostimulant to increase the red Color in the epidermis of apples. The variables analyzed were: production data (kg plant^{-1}, fruits plant^{-1}, average fruit mass and aspects related to fruit quality: pulp firmness, soluble solids content, mineral content in fruits, percentage of red Color in the epidermis of the fruits and incidence of sunburn. The tests carried out to promote the red Color of the fruits showed satisfactory results. However, the tests developed aiming at reducing the incidence of sunburn did not show reliable results, since the environmental conditions, mainly the sunstroke, were not favorable to the development of the damage to the fruits, making it impossible to obtain conclusive information on the efficiency of the $CaCO_3$ product. in reducing the incidence of sunburn in apples. The application of $CaCO_3$ as a sunscreen does not improve the calcium content of the harvested fruits. The application of Physiogrow® Color promotes better allocation of the harvested fruits in categories of greater coloration of the epidermis.
Keywords: *Malus domestica* Borkh., biostimulants, $CaCO_3$.

ESTRATÉGIAS PARA AUMENTAR A COLORAÇÃO VERMELHA E REDUZIR A INCIDÊNCIA DE QUEIMADURAS DE SOL EM MAÇÃS

RESUMO - O objetivo deste estudo foi avaliar a aplicação de $CaCO_3$ em formulação líquida sobre a incidência de queimadura de sol e a qualidade visual de maçãs, bem como testar épocas de aplicação e dosagens de bioestimulantes no aumento da coloração vermelha dos frutos. O estudo foi realizado em parceria com o produtor rural, nos pomares situados no município de Fraiburgo-SC, na safra 2018/2019. Para atender os objetivos propostos, foram conduzidos dois experimentos distintos: experimento 1 - Aplicação de carbonato de cálcio para redução de incidência de queimadura de sol em maçãs, testando diferentes doses do produto comercial, bem como épocas de aplicação e experimento 2 - uso de bioestimulante para aumento da coloração vermelha na epiderme de maçãs, testando doses e épocas de aplicação produto comercial Physiogrow® Color. As variáveis analisadas foram: dados de produção (kg planta^{-1}, frutos planta^{-1}, biomassa média dos frutos e aspectos relacionados à qualidade dos frutos, como firmeza de polpa, conteúdo de sólidos solúveis, teores minerais nos frutos, percentagem de cor vermelha na epiderme dos frutos e incidência de queimadura de sol. Os ensaios realizados para promoção da coloração vermelha dos frutos apresentaram resultados satisfatórios. No entanto, os ensaios desenvolvidos visando redução da incidência de queimaduras de sol não apresentaram resultados confiáveis, pois as condições ambientais, principalmente a insolação, não foram favoráveis ao desenvolvimento do dano aos frutos, impossibilitando a obtenção de informações conclusivas sobre a eficiência do produto $CaCO_3$ na redução da incidência de queimaduras de sol em maçãs. A aplicação de $CaCO_3$ como protetor solar não promove melhoria dos teores de cálcio nos frutos colhidos. A aplicação de Physiogrow® Color promove melhor alocação dos frutos colhidos em categorias de maior coloração da epiderme.
Palavras-chave: *Malus domestica* Borkh., bioestimulantes, $CaCO_3$.

INTRODUCTION

The apple is inserted as the second most produced fruit in the world, whose production was estimated at 83.1 million tons, being surpassed only by the banana. In Brazil, production in 2017 was approximately 1.3 million tons (FAOSTAT, 2019). The states of Santa Catarina and Rio Grande do Sul are responsible for 96% of the Brazilian apple production (PETRI et al., 2011).

The apple tree (*Malus domestica* Borkh.) belongs to the family Rosaceae and subfamily Pomoideae and

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covers 100 genera and more than 2000 species (IUCHI, 2006). Currently, the cultivars ‘Gala’ and ‘Fuji’ together account for around 90% of apple production in the country (PETRI et al., 2011). Of all the fruits produced in Brazil, more than 70% are sold for fresh consumption (ARGENTA et al., 2015).

Apples are classified according to size and category, according to the rules of the Ministry of Agriculture, Livestock and Supply (BRASIL, 2006). The classification of apples is responsible for large differences in revenue. In general, apples with superior qualities, described as Cat Extra and Cat 1, are the ones that reach the highest commercial values, and the inferior qualities, are those that present the lowest values. Currently in Brazil, the main appearance attributes for classifying fruits into categories are: the intensity (percentage) of reddish color and the frequency and size of lesions and visible damage on the surface of the fruits.

Among the damages that compromise the visual quality is sunburn, which is a physiological disorder characterized by spots of yellowish-bronze color that impairs the visual quality of the fruits, in addition to favoring the increased incidence of rot (FELICETTI; SCHARDER, 2009; VALDEBENITO-SANHUEZA et al., 2016). Sunburn is caused by the simultaneous action of light and heat. In this sense, the application of substances that protect the fruit surface has been recommended to reduce the temperature of the skin, reducing the occurrence of sunburn.

Calcium carbonate ($CaCO_3$) in liquid formulation is an alternative that has the potential to be used to reduce the disturbance, since the product forms a thin layer, which reflects part of the light, protecting the fruits from sunburn (LAL; SAHU, 2017). $CaCO_3$ has already been shown to be effective in reducing sunburn on pomegranates (MELGAREJO et al., 2004) and grapes (AHMED et al., 2011). However, there are still no studies that elucidate the effect of $CaCO_3$ in liquid formulation on the incidence of sunburn and fruit quality in apple culture.

The red coating on the skin is the most relevant attribute in the classification of 'Gala' and 'Fuji' apples produced in Brazil. However, in addition to depending on the genetics of the cultivar, the color of the fruits is influenced by climatic conditions, such as light and temperature and by the management of the orchard. The management with growth regulators in the crop can both harm and favor the increase of red color in the epidermis of the fruits. The use of bioregulators is a promising alternative in improving this attribute, however, there are few studies that elucidate its effect on the color of apples (FENILI et al, 2019).

Thus, the objective of this study was to evaluate the effect of applying $CaCO_3$ in liquid formulation on the incidence of sunburn and the visual quality of apples, as well as testing application times and dosages of biostimulant in increasing the red color of the fruits.

MATERIAL AND METHODS

The study was carried out in partnership with the rural producer, in the orchards located in the municipality of Fraiburgo-SC (geographical coordinates: latitude 27º01’S, longitude 50º77’W and altitude 950 m), in the 2018/2019 agricultural year. To meet the objectives of the present study, two different experiments were conducted, described below:

Experiment 1 - Application of calcium carbonate to reduce the incidence of sunburn in apples

The apple cultivars: ‘Elenise’, ‘Baroness’ and ‘Selection M10-09’ were used. The density of planting the orchard was 2,500 plants ha^{-1}, with a spacing of 4 m between rows and 1 m between plants, at the age of 4.

The experimental design used was randomized blocks, with six treatments and six repetitions, each experimental unit being composed of a plant. The treatments used were: 1) control (without application), 2) $CaCO_3$ liquid 4% in a single application [60 days before harvest (DAC)], 3) $CaCO_3$ liquid 2% in two applications (60 DAC and 30 DAC), 4) 2% liquid $CaCO_3$ in single application (60 DAC), 5) 1% liquid $CaCO_3$ in four applications (75 DAC, 60 DAC, 30 DAC and 15 DAC) and 6) 0.5% mineral oil in two applications (60 DAC and 30 DAC). The commercial product Deccoshield® was used as a source of liquid $CaCO_3$.

After harvesting, the fruits were passed through cleaning brushes, simulating the packing house conditions. Then, they were visually evaluated for the presence of sunburn and classified into three groups, according to the incidence: absent, mild and severe (Figure 1). The total incidence was obtained by the sum of fruits considered to have symptoms of mild and severe burns.

FIGURE 1 - Visual assessment for the presence of sunburn in apples.

Experiment 2 - Use of biostimulant to increase the red color in the epidermis of apples

For this trial, apple trees of the cultivar Imperial Gala (cultivar bicolor, with a low percentage of red skin color) were used, aged 12 years old. The planting density of the orchard was 2,500 plants ha^{-1}, with a spacing of 4 m between rows and 1 m between plants.

The experimental design used was randomized blocks, containing seven treatments (Chart 1) and five replications, each experimental unit being composed of a plant. In treatments with two applications, these were performed at 30 DAC and 15 days before harvest (DAC), while in treatments with a single application, this was performed at 15 DAC. The commercial product

Physiogrow® Color presents in its composition carbohydrates and amino acids, with emphasis on the amino acid methionine, which is the precursor of the phytohormone ethylene. The application of treatments, in both experiments, was carried out with a motorized backpack sprayer until close to the drip point, reaching the totality of the canopy of the plants, using an average spray volume equivalent to 1000 L ha^{-1}.

CHART 1 - Description of treatments and times of application of the product to fruits on apple tree cultivar Imperial Gala, harvest 2018/2019.

Treatments	Application times	
	30 DAC	15 DAC
Control	No application	No application
Physiogrow® Color	-	4 L ha^{-1}
Physiogrow® Color	-	8 L ha^{-1}
Physiogrow® Color	-	12 L ha^{-1}
Physiogrow® Color	2 L ha^{-1}	2 L ha^{-1}
Physiogrow® Color	4 L ha^{-1}	4 L ha^{-1}
Physiogrow® Color	6 L ha^{-1}	6 L ha^{-1}

DAC = days before the harvest.

In both orchards used, the plants were managed in a central leader conduction system, according to the recommendations of the apple production system (SEZERINO, 2018) and management practices recommended in the integrated apple production system (SANHUEZA et al., 2006). The variables analyzed were: production, expressed in kg $plant^{-1}$ and obtained by weighing the fruits at harvest; number of fruits / plant, obtained by counting the fruits harvested from each plant during harvest and average biomass of the fruits, obtained from the relationship between total biomass and the total number of fruits harvested.

Aspects related to fruit quality were also evaluated, such as pulp firmness (lbf), determined with the aid of an automatic penetrometer (GÜSS Manufacturing Ltd, Cape Town, South Africa), equipped with an 11 mm diameter tip, in two opposite regions, in the equatorial portion of the fruits, after removing a thin layer of the peel. The levels of SS (ºBrix) were determined in a digital refractometer, model PR201α (Atago®, Tokyo, Japan), with an aliquot of the juice extracted from the fruits. The percentage of red color was determined by visual analysis of the fruits in relation to the coloring of the epidermis, grouping them in three classes, according to the surface of the fruit covered with red coloring, being: 1) >75%, 2) between 50% and 75% and 3) <50%. The values used for the classification were based on the limits of color tolerance, depending on the category of apples sold in Brazil, according to legal regulations of the Ministry of Agriculture, Livestock and Supply (BRASIL, 2006). At the time of harvest, ten fruits per plant were sampled to determine the mineral content (N, P, K, Ca, Mg) and the relationship between these levels in the fruit pulp, according to the methodology described by Schveitzer and Suzuki (2013).

The determination of the epidermis color (red and background color) was carried out with a colorimeter, model CR 400 (Konica Minolta®, Tokyo, Japan), in terms of 'hue' angle (hº), luminosity (L *) and saturation (C *), the readings being taken in the red and background color regions of the fruit. The results expressed in hº define the basic color, with 0º = red, 90º = yellow and 180º = green.

Statistical analysis of the data

For both experiments, analysis of variance was performed, with the percentage data transformed by the sine arc [(x + 1)/100] 1/2, before being submitted to ANOVA. The variables whose results revealed significance ($p < 0.05$), had the comparison of means performed by the Scott-Knott test, at 5% probability of error. Statistical analyzes were performed using the Sisvar program, version 5.3 (FERREIRA, 2011).

RESULTS AND DISCUSSION

Experiment 1

Although they remained in the field for longer than normal, late harvesting, the fruits showed a low incidence of sunburn in the three cultivars evaluated (Table 1). The most severe burn rate was not observed in the 'Selection M10-09' and slightly in the other cultivars. There was only a difference in the incidence of minor burns in the ‘Baroness’. However, this variation is possibly not directly related to the treatments, but rather the variation in the fruit load observed in this cultivar. Plants with a higher number of fruits showed a higher percentage of fruits with the disorder, compared to plants with a lower load. This happened because the plant was more loaded with fruits and they were exposed to solar radiation, because the leaf biomass present in the plants is not enough for the protection of the fruits. In plants with less load, the fruits are protected between the leaves, thus reducing the incidence of burns on the epidermis.

When analyzing the mineral contents (N, P, K, Ca, Mg) present in the fruits, a certain variation was observed between the levels found in apple cultivars (Table 2). This fact, which may be associated with the great difference in fruit load observed between the treated plants, and plants with less fruit load tend to have higher levels of nitrogen in the fruit pulp, and the opposite in more loaded plants. However, when analyzing the levels of Ca, a mineral that plays a major role in maintaining the integrity of membranes and longevity of fruit quality under conditions of prolonged storage, no change in their levels was observed, regardless of the treatment applied, in the cultivars Baronesa and Elenise.

TABLE 1 - Production (kg and fruits plant^{-1}) and average fresh biomass of apple fruits, 'Selection M10-09', 'Baroness' and 'Elenise', submitted to treatments to reduce the incidence of sunburn, harvest 2018/2019.

Treatments	Production		Average fresh biomass (g)	Sunburn		
	kg plant^{-1}	fruits plant^{-1}		absent	mild	severe
			'Seleção M10-09'			
Control	18.7 ns	156.8 ns	120.6 b	97.0 ns	3.0 ns	-
Deccoshield 4% (1x)	18.2**	149.2	124.2 b	94.3	5.7	-
Deccoshield 2% (2x)	20.4	173.6	120.9 b	99.0	1.0	-
Deccoshield 2% (1x)	20.9	178.2	117.8 b	98.3	1.7	-
Deccoshield 1% (4x)	19.9	149.0	135.5 a	96.2	3.8	-
Mineral oil 0,5% (2x)	14.2	122.6	116.1 b	97.3	2.7	-
Averages	18.7	154.9	122.5	97.0	3.0	-
CV (%)	24.9	26.4	6.4	6.2	60.5	-
			'Baronesa'			
Control	15.6 b	124.4 b	128.9 ns	72.7 ns	20.3 b	7.0 ns
Deccoshield 4% (1x)	19.4 b	128.8 b	150.6	70.8	21.7 b	7.6
Deccoshield 2% (2x)	24.6 a	169.0 a	145.5	68.0	26.7 a	5.3
Deccoshield 2% (1x)	17.0 b	119.0 b	142.9	72.5	23.0 b	4.5
Deccoshield 1% (4x)	21.3 a	159.2 a	133.8	62.0	32.4 a	5.6
Mineral oil 0,5% (2x)	21.1 a	153.4 a	138.5	74.9	20.8 b	4.3
Averages	19.8	142.3	140.0	70.1	24.1	5.7
CV (%)	16.9	19.3	9.2	7.6	13.9	31.3
			'Elenise'			
Control	19.4 b	111.4 c	175.1 ns	85.4 ns	9.3 ns	5.3 ns
Deccoshield 4% (1x)	12.8 c	71.4 b	178.9	81.1	10.6	8.3
Deccoshield 2% (2x)	24.7 a	156.0 a	159.0	85.3	10.7	4.0
Deccoshield 2% (1x)	20.7 b	119.4 b	181.3	84.5	11.6	3.9
Deccoshield 1% (4x)	18.2 b	103.8 b	173.2	83.4	8.9	7.7
Mineral oil 0,5% (2x)	12.1 c	71.2 c	170.3	79.7	12.4	7.9
Averages	18.0	105.5	173.0	83.3	10.6	6.2
CV (%)	12.4	15.8	8.4	6.0	22.8	28.5

*Applications made weekly, the first on 01/30/2019, the second on 02/06/2019, the third on 02/13/2019 and the fourth on 02/20/2019. **Means followed by the same letter in the column, do not differ from each other, by the Scott-Knott test ($P \leq 0.05$), ns = not significant ($P \geq 0.05$), CV = coefficient of variation.

TABLE 2 - Mineral content in the pulp of apple fruits and relationships between nutrients in treatments to reduce the incidence of sunburn, 2018/19 harvest.

Treatments	Mineral content (mg Kg^{-1})					Relationships between nutrients		
	N	P	K	Ca	Mg	N/Ca	K/Ca	K+Mg/Ca
				'Baronesa'				
Control	252.8 ns	106.2 b	1295.2 b	49.0 ns	64.8 a	5.2 ns	26.6 b	27.8 b
Deccoshield 4% (1x)	263.8*	122.2 a	1245.8 b	51.0	66.0 a	5.6	26.0 b	27.2 b
Deccoshield 2% (2x)	271.6	126.6 a	1331.4 b	43.2	63.0 a	6.6	31.0 a	32.4 a
Deccoshield 2% (1x)	234.6	129.4 a	1304.4 b	47.0	62.6 a	5.0	27.8 b	29.0 b
Deccoshield 1% (4x)	231.2	99.8 b	1163.6 b	52.4	55.4 b	4.6	23.2 b	24.0 b
Mineral oil 0,5% (2x)	267.4	146.4 a	1582.6 a	43.2	71.8 a	6.2	37.0 a	38.6 a
Averages	253.6	121.8	1320.5	47.6	63.9	5.5	28.6	29.8
CV (%)	16.5	13.5	8.4	16.7	10.5	24.0	15.8	16.1
				'Elenise'				
Control	182.8 b	77.8 b	1051.0 b	50.2 ns	62.4 ns	4.0 ns	21.0 ns	22.2 b
Deccoshield 4% (1x)	183.4 b	85.4 b	1075.8 b	44.8	56.8	4.0	24.4	25.6 b
Deccoshield 2% (2x)	212.6 a	85.8 b	1067.4 b	41.2	59.2	5.2	26.2	27.6 b
Deccoshield 2% (1x)	209.6 a	101.4 b	1111.6 b	41.6	63.8	5.2	26.8	28.4 b
Deccoshield 1% (4x)	223.2 a	156.4 a	1245.2 a	46.0	65.0	4.6	27.4	28.8 a
Mineral oil 0,5% (2x)	213.4 a	144.0 a	1316.2 a	46.2	72.0	4.6	28.4	30.4 a
Averages	204.2	108.5	1144.5	45.0	63.2	4.6	25.7	27.2
CV (%)	10.1	13.3	10.0	11.6	11.8	17.4	14.7	13.8

*Means followed by the same letter in the column, do not differ by the Scott-Knott test (P≤0.05), ns = not significant (P≥0.05), CV = coefficient of variation.

Experiment 2

The production of the plants (kg and fruits plant^{-1}) and the average biomass of the fruits were not influenced by the application of Physiogrow® Color in the cultivar Imperial Gala (Table 3). No premature fruit drop was observed in any of the evaluated treatments, a very important fact, since products that act on ethylene biosynthesis can promote leaf and fruit abscission (SEZERINO, 2018). Regarding the red color of the fruits, a significant increase in the number of fruits with greater color (> 75%) can be observed in the Physiogrow® Color 8 L ha^{-1}, Physiogrow® Color 4 + 4 L ha^{-1} and Physiogrow® treatments Color 6 + 6 L ha^{-1}. In the category of fruits with red coverage between 50 and 75%, there was no difference between treatments. Fruits with less color (<50%), apples from the Physiogrow® Color 4 L ha^{-1}, Physiogrow® Color 8 L ha^{-1} and Physiogrow® Color 4 + 4 L ha^{-1} treatments did not differ statistically from those of the control treatment, while the Physiogrow® Color 2 + 2 L ha^{-1} treatment showed a higher percentage of apples in this category.

TABLE 3 - Production and average fresh biomass of fruits (g) of apple tree cultivar Imperial Gala, subjected to treatments to increase the color of fruits, harvest 2018/2019.

Treatments	Production		Fresh biomass of fruits
	(kg plant^{-1})	(fruits plant^{-1})	(g)
Control	18.7^{ns}	151.6^{ns}	128.5^{ns}
Physiogrow® Color 4 L ha^{-1}	25.6	206.2	127.2
Physiogrow® Color 8 L ha^{-1}	23.8	196.2	120.7
Physiogrow® Color 12 L ha^{-1}	22.0	175.8	124.5
Physiogrow® Color 2 + 2 L ha^{-1}	28.4	218.4	132.5
Physiogrow® Color 4 + 4 L ha^{-1}	25.4	182.2	138.1
Physiogrow® Color 6 + 6 L ha^{-1}	16.9	126.6	133.7
Averages	23.0	179.6	129.3
CV (%)	33,6	17,8	12,7

*ns = not significant (P≥0.05), CV = coefficient of variation.

The biostimulant Physiogrow® Color contributed to the improvement of the coloring of 'Imperial Gala' apples (Table 4). The complexity of these products, whose formulations contain amino acids, algae extract, monosaccharides and humic compounds, associated with the variability of the environment, have mechanisms of doubtful action on plant metabolism (SIERRAS et al., 2016) and their effects are still uncertain (SALVI et al., 2016). However, they can increase the content of anthocyanins and improve the red color coating on the epidermis of apples (FENILI et al., 2018; SCHUHKNECHT et al., 2018).

TABLE 4 - Classification of fruits by percentage of red color of the epidermis (%) in apple trees cultivar Imperial Gala, submitted to the treatments, 2018/2019 harvest.

Treatments	Coloring of fruit epidermis (%)		
	<50%	50-75%	>75%
Control	12.8 c*	52.3^{ns}	34.9 b
Physiogrow® Color 4 L ha^{-1}	14.2 c	48.3	37.6 b
Physiogrow® Color 8 L ha^{-1}	14.1 c	42.3	43.6 a
Physiogrow® Color 12 L ha^{-1}	20.4 b	46.4	33.2 b
Physiogrow® Color 2 + 2 L ha^{-1}	27.6 a	41.5	30.9 b
Physiogrow® Color 4 + 4 L ha^{-1}	13.1 c	47.3	39.5 a
Physiogrow® Color 6 + 6 L ha^{-1}	18.6 b	37.7	43.7 a
Averages	17.3	45.1	37.6
CV (%)	17.1	9.8	10.1

*Means followed by the same letter do not differ, using the Scott-Knott test (p≤0.05), ns = not significant (p> 0.05), CV = coefficient of variation.

The red color of apples (Table 5) did not differ with the application of Physiogrow® Color. The saturation of the red color in fruits treated with Physiogrow® 4 L ha^{-1} and Physiogrow® 12 L ha^{-1} showed no differences in relation to the saturation of apples in the control treatment, while in the other treatments this saturation was reduced, with better results using o Physiogrow® 6 + 6 L ha^{-1}. The brightness of the red color of the apples was greater only in the fruits of the Physiogrow® treatment 4 + 4 L ha^{-1}. Regarding the background color of the epidermis of the apples, none of the color attributes was significant.

The background color of the epidermis is relevant in the evaluation of fruit ripeness, because during its development, the chlorophyll present in the skin and pulp of the apple begins to decrease, the green color begins to pale and the yellow pigments become noticeable. (IWANAMI, 2011). Maintaining the background color of apples that have received Physiogrow® Color is very important, as the yellowing of the background color is a negative attribute caused by some products that increase the red color and ripeness of the apples, as they reduce the life after - harvesting the fruits and decreasing consumer interest, since the yellow color transmits the feeling of a very ripe fruit (LI et al., 2017).

TABLE 5 - Color attributes in the epidermis, in the more and less red regions, of 'Imperial Gala' apples at harvest, according to applications of biostimulants, foliar fertilizers and etefon during ripening, in the 2018/2019 harvest.

Treatments	Luminosity (*L**)	Saturation (*C**)	Hue (*h*°)
		Intensidade de vermelho	
Control	49.3 b*	45.0 a	34.9 ns
Physiogrow® Color 4 L ha^{-1}	48.7 b	43.9 a	33.3
Physiogrow® Color 8 L ha^{-1}	48.3 b	42.7 b	34.6
Physiogrow® Color 12 L ha^{-1}	48.5 b	43.9 a	33.2
Physiogrow® Color 2 + 2 L ha^{-1}	49.2 b	42.7 b	34.3
Physiogrow® Color 4 + 4 L ha^{-1}	54.2 a	42.3 b	36.7
Physiogrow® Color 6 + 6 L ha^{-1}	48.7 b	40.4 c	30.9
Averages	49.6	43.0	34.0
CV (%)	4.6	3.3	9.2
		Background color (yellow)	
Control	71.9 ns	41.6 ns	79.8 ns
Physiogrow® Color 4 L ha^{-1}	70.9	41.2	75.7
Physiogrow® Color 8 L ha^{-1}	71.2	41.8	77.4
Physiogrow® Color 12 L ha^{-1}	71.4	42.0	75.8
Physiogrow® Color 2 + 2 L ha^{-1}	73.1	40.7	79.1
Physiogrow® Color 4 + 4 L ha^{-1}	73.9	41.7	83.2
Physiogrow® Color 6 + 6 L ha^{-1}	69.9	40.8	75.0
Averages	71.8	41.4	78.0
CV (%)	3.2	6.3	6.2

*Means followed by the same letter do not differ, using the Scott-Knott test ($p \leq 0.05$), ns = not significant ($p > 0.05$), CV = coefficient of variation.

The application of the biostimulant did not alter the pulp firmness and the soluble solids of the fruits (Table 6). This is a fundamental characteristic, as it shows that the application of the product did not accelerate the degradation and ripening of the fruits and thus would not have a negative effect on the storage of the fruits.

TABLE 6 - Pulp firmness, soluble solids and titratable acidity of Imperial Gala apple fruits, subjected to treatments to increase the red color of the fruits, 2018/2019 harvest.

Treatments	Pulp firmness (Lib/pol^2)	soluble solids (%)	Titratable acidity (g mL^{-1})
Controle (sem aplicação)	17.7 ns	12.8 ns	0.42 ns
Control	16.9	13.2	0.57
Physiogrow® Color 4 L ha^{-1}	16.9	12.2	0.47
Physiogrow® Color 8 L ha^{-1}	17.0	12.8	0.41
Physiogrow® Color 12 L ha^{-1}	18.1	12.6	0.38
Physiogrow® Color 2 + 2 L ha^{-1}	16.8	12.4	0.37
Physiogrow® Color 4 + 4 L ha^{-1}	16.4	12.6	0.40
Physiogrow® Color 6 + 6 L ha^{-1}	17.1	12.7	0.43
CV (%)	11.8	3.8	34.5

ns = not significant ($p > 0.05$), CV = coefficient of variation.

The application of Physiogrow® Color did not show a statistically significant change for the mineral composition of the apples, nor the K/Ca and K + Mg/Ca ratios (Table 7). However, the values observed in the Physiogrow® Color 12 L ha^{-1} and Physiogrow® Color 4 + 4 L ha^{-1} treatments increased the N/Ca ratio in the fruits, in relation to the other treatments. Apples with N levels higher than 500 mg kg^{-1} and with N/Ca ratio values higher than 14 present higher risks of occurrence of "bitter pit" (AMARANTE et al., 2012). However, the N levels of apples did not exceed 309 mg kg^{-1} between all treatments, while the N/Ca ratios varied from 5.8 to 10.2 between treatments.

TABLE 7 - Mineral contents and relationships between minerals present in the pulp of apple trees cultivar Imperial Gala, subjected to treatments to increase the red color of the fruits, harvest 2018/2019.

Treatments	Mineral contents (mg Kg^{-1})				
	N	P	K	Ca	Mg
Control	258.8 ns	93.2 ns	765.8 ns	45.2 ns	43.6 ns
Physiogrow® Color 4 L ha^{-1}	303.0*	82.4	1121.8	39.8	66.0
Physiogrow® Color 8 L ha^{-1}	295.6	183.4	1020.0	45.6	68.8
Physiogrow® Color 12 L ha^{-1}	297.6	77.6	819.2	34.6	43.6
Physiogrow® Color 2 + 2 L ha^{-1}	273.0	59.8	871.8	43.2	55.6
Physiogrow® Color 4 + 4 L ha^{-1}	309.0	75.2	955.8	30.6	52.6
Physiogrow® Color 6 + 6 L ha^{-1}	302.4	87.0	1128.8	41.6	67.2
Averages	291.3	94.1	954.7	40.1	56.8
CV (%)	10.6	90.6	31.0	29.6	39.2
	Relationships between minerals				
	N/Ca	K/Ca	K+Mg/Ca		
Controle (sem aplicação)	5.8 b	17.0 ns	17.8 ns		
Control	7.6 b	28.4	30.4		
Physiogrow® Color 4 L ha^{-1}	7.0 b	23.8	25.2		
Physiogrow® Color 8 L ha^{-1}	8.8 a	23.8	24.8		
Physiogrow® Color 12 L ha^{-1}	6.6 b	20.8	22.2		
Physiogrow® Color 2 + 2 L ha^{-1}	10.2 a	31.4	33.2		
Physiogrow® Color 4 + 4 L ha^{-1}	8.0 b	28.6	30.4		
Physiogrow® Color 6 + 6 L ha^{-1}	7.7	24.8	26.3		
CV (%)	21.8	29.6	29.8		

*Means followed by the same letter do not differ, using the Scott-Knott test ($p \leq 0.05$), ns = not significant ($p > 0.05$), CV = coefficient of variation.

The application of the product did not result in significant differences for the average mass of the sampled fruits, and for the mineral contents of N, K, P, Ca and Mg. For the relationship between the mineral contents present in the pulp, there was no significant difference for K/Ca and K + Mg/Ca; however, for the N/Ca ratio, the treatments with Physiogrow® Color 12 L ha^{-1} and Physiogrow® Color 4 + 4 L ha^{-1}, differed statistically from the other treatments, presenting a higher ratio (8.8 and 10.2) to the other treatments, calcium is the main nutrient responsible for the quality of the fruit, constituent of the cell wall, while nitrogen is one of the minerals responsible for the growth and development of the fruit. Thus, as the N/Ca ratio increases, greater physiological disorders, greater occurrence of “bitter pitt” and fruits with shorter post-harvest durability, greater damage to cold storage and a higher rate of rot may occur.

CONCLUSIONS

The tests developed aiming at reducing the incidence of sunburn did not present reliable results, since the environmental conditions, mainly the insolation, were not favorable to the development of the damage to the fruits, making it impossible to obtain conclusive information about the efficiency of the $CaCO_3$ product in reducing the incidence of sunburn on apples.

The application of $CaCO_3$ as a sunscreen does not improve the calcium content of the harvested fruits.

The application of Physiogrow® Color promotes better allocation of the harvested fruits in categories of greater coloration of the epidermis.

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