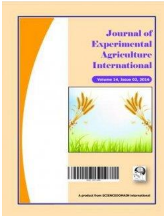

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Strategies for Increasing the Apple Epidermis Red Colored with Physiogrow® Color

Gentil Carneiro Gabardo[1,2*], Lucas Pessoa de Freitas[3], Rafael Hermenegildo Contini[1], Eder Farina[1], Keli Cristina dos Santos[1], Verônica Niara de Souza[2] and Ligia de Lara Furtado[2]

[1]Santa Catarina State University, Agroveterinary Sciences Center, Lages, Brazil.
[2]UNIARP/University Alto Vale do Rio do Peixe, Caçador-SC, Brazil.
[3]Biogrow, Brazil.

Authors' contributions

This work was carried out in collaboration among all authors. Author GCG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors LPF, RHC and EF managed the analyses of the study. Authors KCS, VNS and LLF managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Evaluate different dosages and number of applications of the commercial product Physiogrow® Color on the percentage of red coloration of the epidermis, productivity and fruit quality in 'Royal Gala' apple trees, in the Midwest region of the state of Santa Catarina, Brazil.
Study Design: The experiment was arranged in a randomized block design with five replications.
Place and Duration of Study: The experiment was carried out in the municipality of Fraiburgo-SC, Brazil (latitude 27º01'S, longitude 50º77' W, altitude 950 meters), during the growing seasons of 2017/2018 and 2018/2019.
Methodology: The treatments were: Control (No application), Physiogrow® color (4, 8 and 12 L ha^{-1}) 7 days before harvest (DBH), Physiogrow® Color 2 L ha^{-1} (30 DAC) + 2 L ha^{-1}7 DBH, Physiogrow® Color 4 L ha^{-1} (30 DBH) + 4 L ha^{-1}7 DBH, and Physiogrow® Color 6 L ha^{-1} (30 DBH) + 6 L ha^{-1} 7 DBH. The variables evaluated were: Production (kg plant^{-1} and fruits plant^{-1}), average fresh fruit

**Corresponding author: E-mail: ge.gabardo@gmail.com;*

mass (g), classification of fruits by percentage of red coloration of the epidermis (<50%, 50-80% and > 80%), firmness of the pulp (lb in^{-2}) and soluble solids (°Brix). The harvest was carried out on January 25, 2018 and February 16, 2019, first and second year, respectively. Plant production, as well as pulp firmness of fruits, were not affected by treatments, in both years. Physiogrow® Color promoted better distribution of fruits in categories of greater red coloration of the epidermis and reduction of the percentage of fruits in the category with coloration inferior to 50%, although a different behavior among the harvests was observed. The application of Physiogrow® Color 8 L ha^{-1} 7 DBH contributes to the improvement of the coloration of 'Royal Gala' apples.

Keywords: Malus domestica L.; maturation; post-harvest.

1. INTRODUCTION

In Brazil, apple tree cultivation has evolved a lot in the last years, mainly with the development of management techniques that have increased productivity and quality of fruit produced [1]. In 2017, Brazilian production was about 1.3 million tons, in a planted area of 33,138 hectares [2]. Being this production concentrated in the South Region of the country, with more than 2,300 producers involved [3]. The domestic market is the main destination of the fruits produced, mainly in fresh form, and only 7% for the exportation [4].

The visual quality and size of the fruits play an important role in the national and international markets, since they establish the price of the apple when classified for packaging and export [5,6,7].

According to Iglesias and Alegre [8], the most important visual quality attribute to determine the market value of red or bicolor apples is the amount and intensity of the red epidermis. Considering that at the time of purchase, consumers first analyze the visual appearance of the fruits, only later to consider the internal or nutritional characteristics of the fruits [9,10].

The red color formation in the apple epidermis is linked to a complex series of interactions between environmental factors, orchard management, genetic characteristics of the cultivar and the stage of development of the fruit. The accumulation of anthocyanins corresponds to the genetic potential of the cultivar, which, in turn, is dependent on balanced nutrition and environmental factors such as light and temperature [11].

For Iglesias et al. [12], the easiest and most economical way to improve the color of apples is to plant new cultivars or mutations of cultivars with greater potential to synthesize anthocyanins in the region of interest. The most planted clones of the 'Gala' apple tree, have a tendency to develop greater coloring of the fruits, however, they are still mostly bicolor.

In addition to orchard management techniques that aim to increase fruit exposure to light, commercial products (chemical or natural), fertilizers and growth regulators with biostimulant action, may promote increased red coloration of fruits. The growth regulators based on ethephon release ethylene, a hormone bound to maturation, increasing and intensifying the red coloration of the epidermis of apples [13]. However, ethephon may increase the risk of fruit drop losses in preharvest and reduce storage potential [14]. Some studies have shown that ethephon application may adversely affect the starch hydrolysis rate, reducing pulp firmness, titratable acidity and increasing respiratory rate, carotenoid biosynthesis and chlorophyll degradation [15,16].

Blanke [17] reports that there are always new products on the market with high expectations to increase the anthocyanin synthesis and red color of the apple epidermis, especially leaf fertilizers and biostimulants. Fenili [8] reports the increase in red staining of apple fruits treated with foliar fertilizers based on potassium and micronutrients; however, their effects vary greatly from one year to the next, as well as changes in the quality and storage capacity of the fruits.

Physiogrow® Color, which is an organic liquid leaf fertilizer based on free L-amino acids and organic acids, with potential to be used to improve the coloring of fruits in the apple tree. Since it contains, in its formulation, precursor amino acids of ethylene biosynthesis and anthocyanins, chlorophyllase and monosaccharide regulators.

The objective of the present study was to evaluate different dosages and number of applications of the commercial product Physiogrow ® Color on the percentage of red coloration of the epidermis and fruit quality in 'Royal Gala' apple trees, in the Midwest region of the state of Santa Catarina.

2. MATERIALS AND METHODS

The experiment was conducted in an experimental orchard in the Midwest Region of the state of Santa Catarina, Fraiburgo, Brazil (latitude 27º01'S, longitude 50º77 'W, altitude 950 meters).

'Royal Gala' apple trees grafted on the Marubakaido rootstock with 15-year-old M-9 grafts were harvested in the 2017/2018 and 2018/2019 seasons. The planting density of the orchard used was 2,500 plants ha^{-1}, with a spacing of 4 m between rows and 1 m between plants. The plants were managed in the central leader's system, according to the recommendations of the apple production system and practices recommended in the integrated system of production of apple trees [18,19].

The experimental design was randomized blocks, with seven treatments and five replications. The treatments were: Control (No application), Physiogrow® Color (4, 8 and 12 L ha^{-1}) 7 days before harvest (DBH), Physiogrow® color 2 L ha^{-1} (30 DBH) + 2 L ha^{-1}7 DBH, Physiogrow® Color 4 L ha^{-1} (30 DBH) + 4 L ha^{-1}7 DBH, and Physiogrow® Color 6 L ha^{-1} (30 DBH) + 6 L ha^{-1}7 DBH. The application of the treatments was performed with a motorized costal spray, containing a tip with three spray tips D-S fan type, using a volume of syrup equivalent to 1000 L ha^{-1}, until the point of drip.

The harvest was carried out on January 25, 2018 and February 16, 2019, first and second year, respectively. The variables evaluated were: Production (kg $plant^{-1}$ and fruits $plant^{-1}$), average fresh fruit mass (g), classification of fruits by percentage of red coloration of the epidermis (<50%, 50-80% and > 80%); firmness of the pulp (Lb in^{-2}) and soluble solids (°Brix) according to Scolaro et al [20].

The firmness of the pulp was determined with the aid of an analogue penetrometer (GÜSS), equipped with a 11 mm diameter tip, in two opposite regions, in the equatorial portion of the fruits, after removal of a thin layer of the bark.

The statistical analysis of the data was performed through analysis of variance, the variables whose results revealed significance (*P* <0.05), were submitted to the comparison of means by the Scott-Knott test, and or regression analysis at 5% probability Statistical analyzes were performed by Sisvar®, version 5.6. [21]

3. RESULTS AND DISCUSSION

In both years, the application of Physiogrow® Color did not promote alteration or reduction in the production (kg and fruits $plant^{-1}$) and in the average fresh mass of the fruits of the treated plants compared to the control treatment (Table 1). This fact, of great importance, as it shows that the product did not cause too much acceleration of fruit maturation, which could cause pre-harvesting of fruits, as reported by Sun et al. [14], who identified this problem in apple trees treated with etephon.

The pulp firmness of the harvested fruits did not change, in both evaluated harvests. However, differences were observed in soluble solids contents between seasons (Table 2). In the 2017/2018 year, the plants treated with the split application of Physiogrow® Color, regardless of the dose, presented lower levels of soluble solids. In the 2018/2019 year, the treatments Physiogrow® Color 8 L ha^{-1} and Physiogrow® Color 12 L ha^{-1} applied to 7 DBH did not differ from the control treatment, which presented the lowest concentrations of soluble solids in comparison to the other treatments. The increase of soluble solids concentration in the fruits can be attributed to higher ethylene production, which in turn increases starch hydrolysis, respiration and soluble solids content, as well as increasing the yellowing of the fruit, leading to maturation. or not, to reduce the flesh firmness of the fruits [16,22,23].

The application of Physiogrow® Color promoted a better fruit distribution in categories with higher commercial value. That is, reduction of the percentage of fruits with epidermal coloration inferior to 50% and increase of the percentage of fruits with red color of the epidermis superior to 80%. Differential behavior was observed between the harvests studied (Table 3). In season 2017/2018, the plants were treated with Physiogrow® Color 8 L ha^{-1} 7DBH, which reduced the production of fruits with red epidermis color by 50% and 51%, and increased 187, 6% of fruits allocated in the category of greater coloration of the epidermis, compared to

Table 1. Production (kg and fruits plant^{-1}) and average fresh mass of the fruits (g) of 'Royal Gala' apple trees submitted to different treatments. 2017/2018 and 2018/2019. Fraiburgo-SC, Brazil, 2019

Treatments	Production		Fresh mass of the fruits (g)
	kg plant^{-1}	fruits plant^{-1}	
Season 2017/2018			
Control (No application)	17,2^{ns}	169,3^{ns}	102,0^{ns}
Physiogrow Color 4L ha^{-1}	19,4	209,3	93,7
Physiogrow Color 8L ha^{-1}	20,9	196,3	106,9
Physiogrow Color 12L ha^{-1}	17,6	175,3	101,0
Physiogrow Color 2 + 2L ha^{-1}	26,8	277,3	99,5
Physiogrow Color 4 + 4L ha^{-1}	24,2	240,5	101,5
Physiogrow Color 6 + 6L ha^{-1}	22,8	215,5	107,8
Average	21,2	211,9	101,8
CV (%)	31,5	35,7	9,9
Season 2018/2019			
Control (No application)	18,7^{ns}	151,6^{ns}	128,5^{ns}
Physiogrow Color 4L ha^{-1}	25,6	206,2	127,2
Physiogrow Color 8L ha^{-1}	23,8	196,2	120,7
Physiogrow Color 12L ha^{-1}	22,0	175,8	124,5
Physiogrow Color 2 + 2L ha^{-1}	28,4	218,4	132,5
Physiogrow Color 4 + 4L ha^{-1}	25,4	182,2	138,1
Physiogrow Color 6 + 6L ha^{-1}	16,9	126,6	133,7
Average	23,0	179,6	129,3
CV (%)	33,6	17,8	12,7

** ns: not significant (P>.05)*

Table 2. Firmness of pulp (Lb in^{-2}) and soluble solids (ºBrix) of the fruits of 'Royal Gala' apple trees submitted to different treatments. 2017/2018 and 2018/2019. Fraiburgo-SC, Brazil, 2019

Treatments	Firmness of pulp (Lb in^{-2})	Soluble solids (ºBrix)
Season 2017/2018		
Control (No application)	21,2^{ns}	13,7a
Physiogrow Color 4L ha^{-1}	21,5	11,5a
Physiogrow Color 8L ha^{-1}	21,7	11,6a
Physiogrow Color 12L ha^{-1}	22,8	11,4a
Physiogrow Color 2 + 2L ha^{-1}	22,6	9,0b
Physiogrow Color 4 + 4L ha^{-1}	21,2	9,7b
Physiogrow Color 6 + 6L ha^{-1}	20,8	10,1b
Average	21,7	11,0
CV (%)	5,7	13,8
Season 2018/2019		
Control (No application)	17,7^{ns}	12,1 b
Physiogrow Color 4L ha^{-1}	16,9	13,4 a
Physiogrow Color 8L ha^{-1}	16,9	12,0 b
Physiogrow Color 12L ha^{-1}	17,0	11,9 b
Physiogrow Color 2 + 2L ha^{-1}	18,1	13,9 a
Physiogrow Color4 + 4L ha^{-1}	16,8	13,7 a
Physiogrow Color 6 + 6L ha^{-1}	16,4	13,2 a
Average	17,1	12,9
CV (%)	11,8	4,9

Means followed by the same letter in the column do not differ from one another by the Scott-Knott test (P=.05). ns: not significant (P>.05)

untreated plants (Control). Physiogrow® Color 12 L ha^{-1} 7 DBH and Physiogrow® Color 6 L ha^{-1} 30DBH + 6 L ha^{-1} 7 DBH treatments also increased the percentage of fruits in the higher staining category. In the second harvest, 2018/2019, there was greater variation among treatments, mainly in the percentage of fruits in the category of less staining that was quite irregular. However, the gain in the percentage of fruits in the highest color category observed in the previous crop, was repeated again in this harvest with the treatments Physiogrow® Color 8 L ha^{-1} 7 DBH, but with less intensity, only 24,9%, not differing (4 L ha^{-1} 30 DBH + 4 L ha^{-1} 7 DBH) and (6 L ha^{-1} 30 DBH + 6 L ha^{-1} 7 DBH)], which increased by 13.2% and 25,2% the fruits of greater red coloration of the epidermis, respectively.

It is worth mentioning that there was a difference of 22 days in the date of harvest between seasons. Since the 2017/2018 harvest was held in ideal harvesting point for storage, while the crop 2018/2019 was held in later time, and there may be impairment of the observed data, the natural ripening of the fruit.

These results were evident in the data presented in Tables 2 and 3, characterized by the lower firmness of pulp, higher concentration of soluble solids and greater allocation of fruits in the category of greater red coloration of the epidermis.

For Severino et al. [24], in the early harvest cultivars, where the light level is adequate, the main limiting factor for anthocyanins and red color accumulation in the apple epidermis is temperature, since during the maturation stage of these cultivars, thermal amplitude and especially the night temperature are generally not ideal for anthocyanin synthesis. On the other hand, in late cultivars, the factor that becomes limiting is light, since the temperature and its amplitude are favorable for anthocyanin synthesis and red color.

In the second year of the study, it was observed an increase in the yellow background color in the fruits harvested due to the later harvest season and climatic conditions unfavorable to the development of the red color in the fruits, marked by rainy weeks and cloudy days. The yellowing of the background color is another negative attribute, since in addition to reducing the post-harvest life of the fruits, the interest of the consumers also diminishes, since the yellow color conveys the sensation of a very mature fruit [22]. The red color formation in the apple epidermis starts simultaneously with the yellowing of the background color of the fruit,

Table 3. Red coloration of the epidermis (%) of fruits produced by 'Royal Gala' apple trees submitted to different treatments. 2017/2018 and 2018/2019. Fraiburgo-SC, Brazil, 2019

Treatments	Red coloration of the epidermis (%) of fruits		
	<50%	50-80 %	>80%
Season 2017/2018			
Control (No application)	30,9 a	58,6^{ns}	10,5 b
Physiogrow Color 4L ha^{-1}	32,5 a	57,4	10,0 b
Physiogrow Color 8L ha^{-1}	15,9 b	53,9	30,2 a
Physiogrow Color 12L ha^{-1}	30,7 a	45,2	24,1 a
Physiogrow Color 2 + 2L ha^{-1}	38,5 a	49,6	11,9 b
Physiogrow Color 4 + 4L ha^{-1}	49,0 a	46,4	4,6 b
Physiogrow Color 6 + 6L ha^{-1}	35,1 a	44,7	20,2 a
Average	33,2	50,8	15,9
CV (%)	16,7	10,6	24,4
Season 2018/2019			
Control (No application)	12,8 c	52,3^{ns}	34,9 b
Physiogrow Color 4L ha^{-1}	14,2 c	48,3	37,6 b
Physiogrow Color 8L ha^{-1}	14,1 c	42,3	43,6 a
Physiogrow Color 12L ha^{-1}	20,4 b	46,4	33,2 b
Physiogrow Color 2 + 2L ha^{-1}	27,6 a	41,5	30,9 b
Physiogrow Color 4 + 4L ha^{-1}	13,1 c	47,3	39,5 a
Physiogrow Color 6 + 6L ha^{-1}	18,6 b	37,7	43,7 a
Average	17,3	45,1	37,6
CV (%)	17,1	9,8	10,1

*Means followed by the same letter in the column do not differ from one another by the Scott-Knott test (P=.05). * ns: not significant (P>.05)* when chlorophyll degradation and carotenoid synthesis is occurring. For Tijskens et al. [25], the most important process in the formation of red color is related to the degradation of chlorophyll, rather than the formation of any flavonoid.

4. CONCLUSION

Physiogrow® Color does not affect the production of the plants, nor the firmness of the fruit pulp produced. However, it may influence the content of soluble solids (°Brix).

Physiogrow® Color improves the distribution of fruits in categories of greater red color of the epidermis and reduces the percentage of fruits in the category with coloration inferior to 50%, with variable intensity between the years.

The application of Physiogrow® Color 8 L ha^{-1} 7 DBH contributes to the improvement of the coloration of 'Royal Gala' apples.

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COMPETING INTERESTS

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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