GUILHERME DUMBÁ MONTEIRO DE CASTRO

HASS AVOCADO BEHAVIOR ON DIFFERENT ROOTSTOCKS AND RESPONSE TO PACLOBUTRAZOL APPLICATIONS

Thesis submitted to the Plant Science Graduate Program of the Universidade Federal de Viçosa, in partial fulfillment of the requirements for the degree of *Doctor Scientiae.*

Adviser: Carlos Eduardo Magalhães dos Santos

Co-adviser: Willian Rodrigues Macedo

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Carlos Eduardo Magalhães dos Santos
Adviser

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To God.

To my parents for all the love.

To the Universidade Federal de Viçosa for the opportunity to complete the graduate course.

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“Come abacate que passa.”.
(Vovó Juju)

BIOGRAPHY

GUILHERME DUMBÁ MONTEIRO DE CASTRO, son of Edvaldo José de Castro and Geralda Aparecida Dumbá de Castro, was born in Curvelo city, Minas Gerais, Brazil, on July 12, 1991.

In July 2010, He joined the Universidade Federal dos Vales do Jequitinhonha e Mucuri, graduating in Agronomy in July 2017. He completed an undergraduate exchange program from September 2013 to February 2015, at the Sligo Institute of Technology, Sligo, Republic of Ireland.

In August 2017, he started the Graduate Program in Fitotecnia, at the master's level, at the Universidade Federal de Viçosa, Viçosa-MG, having defended his dissertation on July 22, 2019. In August 2019, He joined the course of Doctor Scientiae in Plant Science at the Universidade Federal de Viçosa, submitting to the thesis defense on December 21, 2022.

ABSTRACT

CASTRO, Guilherme Dumbá Monteiro, D.Sc., Universidade Federal de Viçosa, December, 2022. **Hass avocado behavior on different rootstocks and response to paclobutrazol applications**. Adviser: Carlos Eduardo Magalhães dos Santos. Co-adviser: Willian Rodrigues Macedo.

The world market for the consumption and production of fruits and vegetables, as well as several other sectors, has undergone rapid changes, mainly due to the pandemic caused by the Covid19 virus. Consumers are showing more interest in healthy eating. The avocado has proven to be one of the most prominent fruits regarding new eating habits, especially the Hass cultivar. The change of habits even before the start of the pandemic in 2020, and because avocado has many health benefits, world consumption of avocados increased from 3.5 million tons in 2007 to 5. 9 million tons in 2018. Its average consumption increased in Brazil from 600 grams/inhabitant/year, in 2016, to 900 grams in 2018. Brazil has proven to be an essential player in the avocado chain, with its planted area increasing yearly and a high capacity to supply quality products at different times. Despite this, productivity levels are still below the world average. The Cerrado Mineiro region has faced severe falls in its plant productivity over the years. It justifies the need to develop research with the most produced cultivars in the country. The present study aimed to analyze two scientific articles that can be used as a basis for new technology development for the Alto Paranaíba region, one of the largest avocado producers in Minas Gerais. The first article determines more suitable rootstocks for the Hass canopy cultivated in the Alto Paranaíba region through physiological, biometric, and production analyses, allowing better decisions in the orchard implantation. All Hass plants showed different physiological behavior when grafted in distinct cultivars without showing significant differences in the productivity factor. The Ouro Verde and Hass proved to be the most promising for use as a rootstock in the Minas Gerais cerrado. The second article analyzed the avocado Hass plant cultivated in eight different doses of paclobutrazol, 0,0; 0,5; 0,25; 0,75; 0,85; 1,0; 2,0 and 3,0 g.m-1, application in soil and foliar, in four application months, December 2021, March, May, and June 2022. It analyzed shoot length, panicle number and type, and fruit number. Paclobutrazol could reduce the shoot length in all applications; in the soil, the product also improves the plant's total panicles and determinate panicles number, possibly leading to more fruits. The development and continuation of the studies carried out in this thesis are essential; we can increase the production of the state of Minas Gerais, also helping in the national output. We will be able to produce with more quality and quantity, using methods not yet used worldwide and developing technologies for avocado producers consciously and sustainably.

Keywords: *Persea americana* Mill. Paclobutrazol. Rootstocks. Hass canopy.

RESUMO

CASTRO, Guilherme Dumbá Monteiro, D.Sc., Universidade Federal de Viçosa, dezembro de 2022. **Comportamento do avocado Hass sobre diferentes porta-enxertos e resposta a aplicações de paclobutrazol**. Orientador: Carlos Eduardo Magalhães dos Santos. Coorientador: Willian Rodrigues Macedo.

O mercado mundial de consumo e produção de frutas e hortaliças, assim como diversos outros setores, tem passado por rápidas mudanças, principalmente devido à pandemia da COVID-19. Os consumidores estão demonstrando mais interesse em uma alimentação saudável. O abacate é uma das frutas de maior destaque, quando se trata de novos hábitos alimentares. Com a crescente mudança de hábitos, antes do início da pandemia em 2020, e porque o abacate é uma fruta comprovadamente com muitos benefícios para a saúde, o consumo mundial de abacate aumentou de 3,5 milhões de toneladas em 2007 para 5,9 milhões de toneladas em 2018, e seu consumo médio no Brasil aumentou de 600 gramas/habitante/ano, em 2016, para 900 gramas em 2018. O Brasil tem se mostrado um importante player na cadeia do abacate, com área plantada crescendo a cada ano e com alta capacidade de fornecer produtos de qualidade em várias épocas do ano. Apesar disso, os níveis de produtividade ainda estão abaixo da média mundial, e existe uma crescente demanda para a implantação de novas áreas, com mais de 400 hectares apenas na região do Alto Paranaíba, no Estado de Minas Gerais. A agricultura sempre esteve presente na região. Assim, à necessidade de desenvolver pesquisas com as cultivares mais produzidas no país, não só por possibilitar avanços tecnológicos mundiais para esta cultura que movimenta milhões de dólares no mercado internacional; mas também, por ser um alimento de subsistência em países subdesenvolvidos. Os avanços dessa cultura permitem, mesmo que gradativamente, a redução da fome. O presente estudo teve como objetivo desenvolver e analisar dois artigos científicos que possam servir de base para o desenvolvimento de novas tecnologias para a região do Alto Paranaíba, uma das maiores produtoras de abacate de Minas Gerais. O primeiro artigo determina porta-enxertos mais adequados para a copa Hass cultivada na região do Alto Paranaíba por meio de análises fisiológicas, biométricas e de produção, permitindo melhor decisão na implantação do pomar. Neste trabalho, verificamos que todas as plantas Hass apresentaram comportamento fisiológico diferente quando enxertadas em diferentes cultivares, sem apresentar diferenças significativas no fator produtividade. As cultivares Ouro Verde e Hass mostraram-se as mais promissoras para uso como porta-enxerto no cerrado mineiro. O segundo artigo avalia o abacateiro cultivar Hass cultivado em oito diferentes doses de paclobutrazol, 0,0; 0,5; 0,25; 0,75; 0,85; 1,0; 2,0 e 3,0 g.m^{-1} (grama por metro linear de copa), com duas formas de aplicação, solo e via foliar, em quatro meses de aplicação, dezembro de 2021, março, maio e junho de 2022. Foram analisados comprimento da parte aérea, número e tipo de panículas e número de frutos. O paclobutrazol conseguiu reduzir o comprimento do fluxo vegetativo em todas as formas de aplicação; o produto também aumentou o número de panículas totais e panículas determinadas na planta, quando aplicados via solo, podendo levar a mais frutos. Com o desenvolvimento e continuação dos estudos realizados nesta tese, podemos aumentar a produção do estado de Minas Gerais, auxiliando também, na produção nacional. Poderemos produzir com mais qualidade e quantidade, utilizando métodos ainda não utilizados no mundo, desenvolvendo tecnologias para produtores de abacate de forma consciente e sustentável.

Palavras-chave: *Persea americana* Mill. Paclobutrazol. Porta enxerto. Copa Hass.

SUMMARY

1. GENERAL INTRODUCTION

Agriculture has always existed in the Alto Paranaíba region in Minas Gerais, Brazil. Araxá, Carmo do Paranaíba, Coromandel, Ibiá, Lagoa Formosa, Monte Carmelo, Rio Parnaíba, Sacramento, and São Gotardo are cities in this region. Monocultures of vegetables such as carrots, potatoes, garlic, and strawberries and the cultivation of commodities such as coffee, sugar cane, soybeans, and corn mark the area's history.

Fruit crops grew initially with the Tsuge Group and COOPADAP, respected regional companies, starting their projects with planting lychee, avocado, and pitaya. Other farmers, because of the avocado success, decided to invest their land, time, and resources in avocado tree cultivation, which today is very profitable and with great potential for growth in productivity and fruit quality.

The world market for the consumption and production of fruits and vegetables, as well as several other sectors, has undergone rapid changes, mainly due to the pandemic caused by the Covid19 virus. There is no doubt that consumers are showing more interest in healthy eating. People spent more time at home, and when faced with the severity of the disease, they realized the importance of healthy habits. Additionally, a worldwide economic downturn and the rising cost of growing fruits and vegetables, harvesting these products, and delivering them safely to the market have increased pressure on supply chains (MALTA, 2020).

Regarding new eating habits, avocado has proven to be one of the most prominent fruits, especially the Hass cultivar, popularly known as avocado (Figure 1). With the growing change in eating habits even before the pandemic in 2020, and because avocado has many health benefits, world consumption of avocados increased from 3.5 million tons in 2007 to 5. 9 million tons in 2018. Its average consumption increased in Brazil from 600 grams/inhabitant/year, in 2016, to 900 grams in 2018. (ABPA, FAO, 2022).

Figure 1- Avocado fruits cv. Hass from the orchard belonging to the Tsuge group.

SOURCE: Personal Archive

Avocados are grown on 16,300 hectares of Brazilian territory. Among fruits, it is the 17th in the area and Gross Production Value (GVP), with R$ 473 million calculated in 2020 by the Brazilian Institute of Geography and Statistics (IBGE). In the volume of harvested product, it occupies the 15th place, with 266 thousand tons. The State of São Paulo is the largest avocado producer in Brazil, with 50.6% of production; Minas Gerais, with 28.6%, and Paraná, the third-largest producer, responsible for 9.7% of harvests. IBGE points out that in Brazil, there has been a 36.12% increase in the planted area with avocados since 2001 and a 35.92% production growth in the same period.

The cultivation of the 'Hass' avocado and tropical avocados has increased a lot in Brazil. Avocado is a cultivar Guatemalan Mexican hybrid with a buttery texture and a light green interior; its skin is rough. It changes color from green to black when ripe; it has more oil and less water than tropical avocados like ‘Fortuna’, ‘Breda’, ‘Geada’, ‘Margarida’, and ‘Quintal’, which are widely consumed in Brazil mainly for vitamins but have low value in the international market. The fruits of the 'Hass' cultivar are fruits with high amounts of oil, which can exceed 20%, creamier pulp, and rich in flavor, making it the most consumed variety in the world, mainly in savory dishes.

The avocado, the name given to Hass here in Brazil, is an avocado cultivar smaller than the others; it was developed and cultivated by the amateur horticulturist Rudolph Hass, who gave his name to the cultivar. Studies show that its global demand will grow at an annual rate of almost 5% until 2025, surpassing the US $8 billion generated globally, according to an estimate by the HAB (Hass Avocado Board 2022). They provide the sector with the consolidated market and supply data, conduct research, and bring people together to work collectively toward growth that benefits everyone.

Brazil has the harvest season in March and ends in September in most producing regions, which leaves a bottleneck from October to February. This lack is filled with the use of tropical avocados, with higher amounts of water and less oil in the pulp when compared to Hass. From October to February, Hass is out of season. During this period, we find the highest prices on Hass in most supply centers.

Brazil has proven to be an essential player in the avocado chain, with its planted area increasing yearly and a high capacity to supply quality products at different times. Despite this, productivity levels are still below the world average. There is a growing demand for producers to implement new areas, with more than 400 hectares only in the Alto Paraníba region. It justifies the need to develop research with the most produced cultivars, in the country, not only for enabling global technology. Advances in this crop generate millions of dollars on the international market and for being a subsistence food in underdeveloped countries; advances in this culture allow, even if gradually, combat world hunger.

Based on these initially raised considerations, the present study aimed to evaluate two scientific articles for new technology development for the Alto Paranaíba region, one of the largest avocado producers in Minas Gerais.

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2. SCIENTIFIC ARTICLE 1

Vegetative, productive, and physiological characterization of different avocado rootstocks for the Hass canopy

ABSTRACT

Avocado crops in Brazil are most cultivated with grafted seedlings. The use of rootstock originating from plants without a defined variety is the most common. The work objective was to determine more suitable rootstocks for the Hass canopy cultivated in the Alto Paranaíba region through physiological, biometric, and production analyses, allowing better decisions in the orchard implantation. A 5x3 factorial scheme was used, with five treatments, consisting of avocado rootstock cultivars (Ouro Verde, Quintal, Margarida, Hass, and Fortuna) and three evaluation times, in different stages, vegetative, flowering, and fruiting. We collected data regarding productivity, fruit quality, biometrics, and plant physiology, using an IRGA. The analyzed plants showed good canopy adaptability in the cerrado region since it was possible to observe adaptations in the foliar pigments and gas exchange levels in response to adverse conditions. All Hass plants showed different physiological behavior when grafted in distinct cultivars without showing significant differences in the productivity factor. The Ouro Verde and Hass proved to be the most promising for use as a rootstock in the Minas Gerais cerrado.

Keywords - *Persea americana* Mill. Propagation. Tropical rootstocks. Alto Paranaíba.

INTRODUCTION

The avocado tree can be propagated sexually, via seed, or asexually, via vegetative propagation. The vegetative method is the most used due to the mother plant genetic characteristics conservation, the juvenile phase reduction, and the uniform plants obtaining (YAMAZOE & VILAS BOAS, 2003; LORETI & MORINI, 2008). Grafting, an asexual propagation most used in avocados, is a method of union between scion and rootstock, which will soon form a single plant growth unit through the vascular connection between the two stem segments (JANICK, 1966; JEFFREE & YEOMAN, 1983).

It is expected that there is a union between the cambial tissues of both parties involved, allowing the raw sap conduction to the apex of the grafted plant, avoiding scion dehydration, without impeding exchanges gaseous, essential for graft attachment, as well as the transports to the root system (KOLLER, 1984). In fruit crops, such as mango and citrus, the rootstock influences the canopy physiology, increasing vigor, productivity, and production anticipation and providing tolerance to salinity, diseases, and pests. In addition, rootstock rusticity allows better adaptation and phytosanitary conditions, with better canopy adaptability (LEDO, 1991).

Unlike other fruit species, the avocado tree in the Brazilian cerrado does not have a recommendation for specific rootstock use. Although most avocado crops in Brazil are done with grafted seedlings, the rootstock is still obtained from seeds originating from uncultivated plants without a defined variety. In recent years, research has focused on getting clonal rootstocks to improve fruit production and quality, reduce plant size, incorporate tolerance to diseases, such as *Phytophthora cinnamomi*, and make cultivation more flexible abiotic stress conditions (ARPAIA; MENGE, 2004).

A clonal rootstock disadvantage is the pivoting root absence, which results in plants that are more sensitive to water lack and the action of the wind (ROSE, 2003). It is challenging to use this type of seedling in crops in Minas Gerais, where the orchards are not irrigated, in addition to the clonal seedling price, making the production chain more expensive (GABOR, 1991; WESSELS, 1996; WHILEY, 2013).

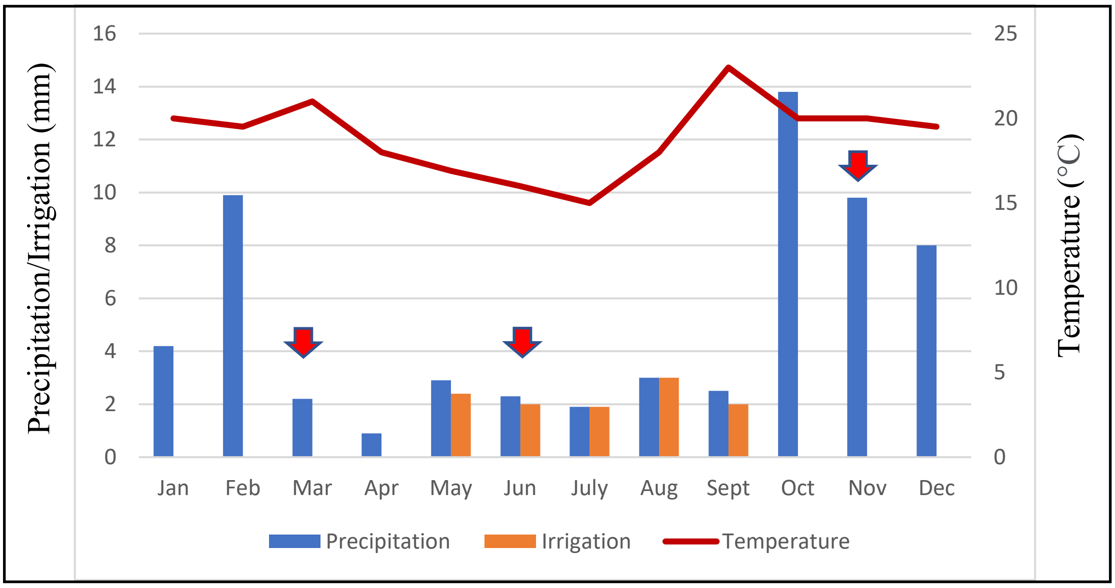
Perennial species cultivated from the grafting process may present incompatibility between scion and rootstock at the grafting time or even in an orchard that has already formed (BARON et al., 2018). Physiological studies such as gas exchange analysis, productivity assessment, vegetative growth, and leaf pigments are essential for analyzing the adaptation to the growing environment.

Thus, the work objective is to determine the most suitable tropical rootstocks for the Hass variety grown in the Alto Paranaíba region through physiological, biometric, and production analyses.

MATERIAL AND METHODS

The experiment was carried out in the Tsuge Group orchard on Lot 15- PADAP, Km 108, highway MG-235, Rio Paranaíba, Minas Gerais, Brazil, 19°24'47.2"S 46°15'25.7"W. The experimental area consists of a 4 (four) year old avocado orchard, irrigated with a center pivot, with plants from seedlings grafted in 2018 and planted in the same year. A Valley Meteorological Station near the farm collected the environmental conditions (Figure 1).

FIGURE 1 - Average precipitation values, irrigation, and temperature in the experimental area in 2021.



The red arrows indicate the analysis moments. March: vegetative analysis; June: flowering analysis and November: fruiting analysis.

The experiment consists of a factorial scheme, 5x3, with five treatments, consisting of avocado rootstock cultivar (Ouro Verde, Quintal, Margarida, Hass, and Fortuna) and three evaluation times, composed of phenological stages.

Vegetative, when more than 50% of the plants had new shoots; flowering, when more than 50% had emitted panicles and fructification, during the fruit set. Furthermore, four experimental units were adopted per plot, where each experimental unit consisted of three trees, totaling 60 plants under study.

In the experimental area, flowering started by the end of June for all treatments, achieving full flowering and anthesis in July and August, an earlier flowering when compared to other orchards that usually have full flowering in August and September.

For the biometric and productive parameters, the following were measured: plant height (meters), trunk diameter (meters), and crown diameter (meters), with a tape measure aid. The trunk diameter was performed 2 cm above the grafting point. The evaluations occurred in March 2021 and 2022, when the plant was vegetative after harvest and before pruning. It was also evaluated with a digital scale (Jundiai model BJ-750) the accumulated pruning in the year. An open vase system was used, with the plant center opening through and exposing the branches to the sun's rays. The productivity of each rootstock was evaluated by weighing the fruits of the harvest during the farm harvest months.

Regarding the production analyses and the fruit quality, the following were measured: longitudinal diameter (cm), latitudinal diameter (cm), and oil content in the fruit (%). The fruit's biometric parameters were obtained with a caliper aid. The oil content was measured using microwave drying; all the fruits had approximately 21% dry matter, and extraction was done with 98% hexane. A composite pulp sample of five fruits was obtained, and a 2g sample portion was used.

For the gas exchange analyses, each plant was divided into quadrants, excluding the shaded quadrant to avoid variation in the CO2 assimilation, stomatal conductance, and transpiration, since plants subjected to shade have lower values for these variables, in addition to reductions in chlorophyll contents (Engel, 1989).

Measurements were taken between 8:00 am and 11:30 am. Three leaves per plant were analyzed, one in each canopy quadrant, adopting the 3rd leaf of the 1st cycle growth, in the middle third, as each treatment index leaf because they represent the fully developed and expanded leaves and are more photosynthetically active in the plant. According to DWYER et al. (1989), maximum photosynthesis is reached around one week after full leaf expansion. The evaluations were carried out on 03/24/2021, 06/24/2021, and 11/24/2021, using the infrared gas exchange analyzer, IRGA, to acess the photosynthetic assimilation rate (A), stomatal conductance (gs), internal CO2 concentration (Ci), leaf transpiration (E), and the A/E ratio, in the three previously identified leaves. For better results, all the days of data collection were chosen based on the weather conditions, always on sunny days, with fewer clouds and low humidity in the experimental site. Physiologic analyses were made before any pruning intervention.

These three evaluated leaves were collected and stored in a styrofoam box with ice for preservation and sent to the Physiology and Metabolism Laboratory of Plant Production at Universidade Federal de Viçosa - Campus Rio Paranaíba. For chlorophylls and carotenoids determination, 1cm^2 of leaf blade was collected and deposited in a tube sealed with aluminum paper to avoid photo-oxidation, and 80% acetone (15ml) was added. Seventy-two hours later, it was read in a spectrophotometer (UV-Vis PerkinElmer Lambda 25) (Macedo et al., 2013).

Statistical analyzes were performed using the Speed Stat Spreadsheet software, version 2.6, where data were submitted to ANOVA, and means were compared using the SNK and Tukey test at 5% error probability.

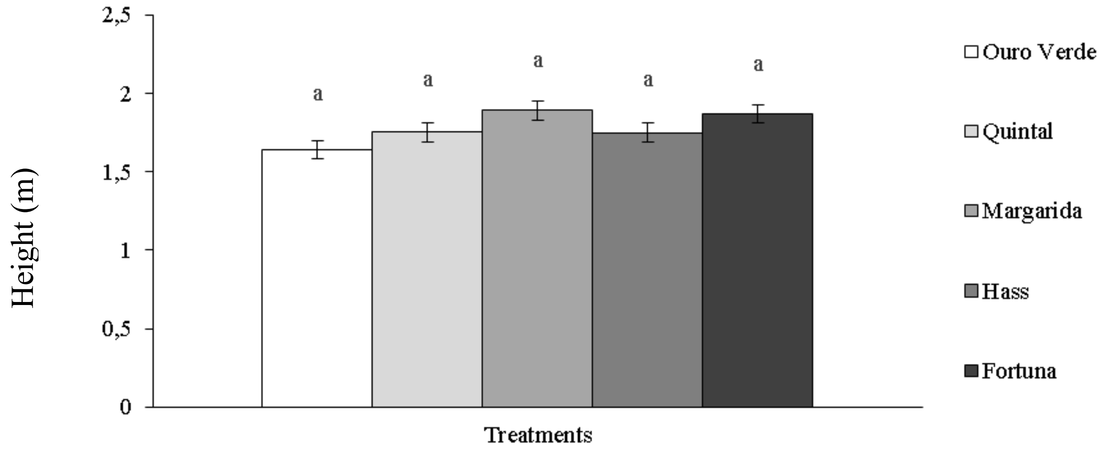
RESULTS AND DISCUSSION

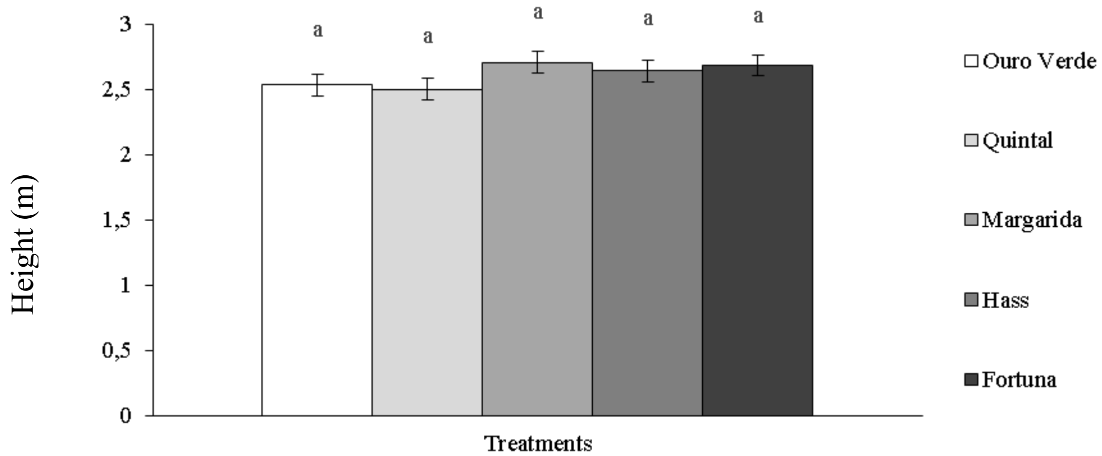
Biometric analysis

The biometric parameters did not significantly differ between the different cultivars in 2021 and 2022. The height trait did not express a significant difference(Figure 2), as well as canopy diameter (Figure 3) and trunk diameter (Figure 4).

Margarida and Fortuna cultivars expressed the highest pruning values in 2021. In the second year, 2022, Margarida was again the most pruned plant, reaching 68 kg (Figure 5).

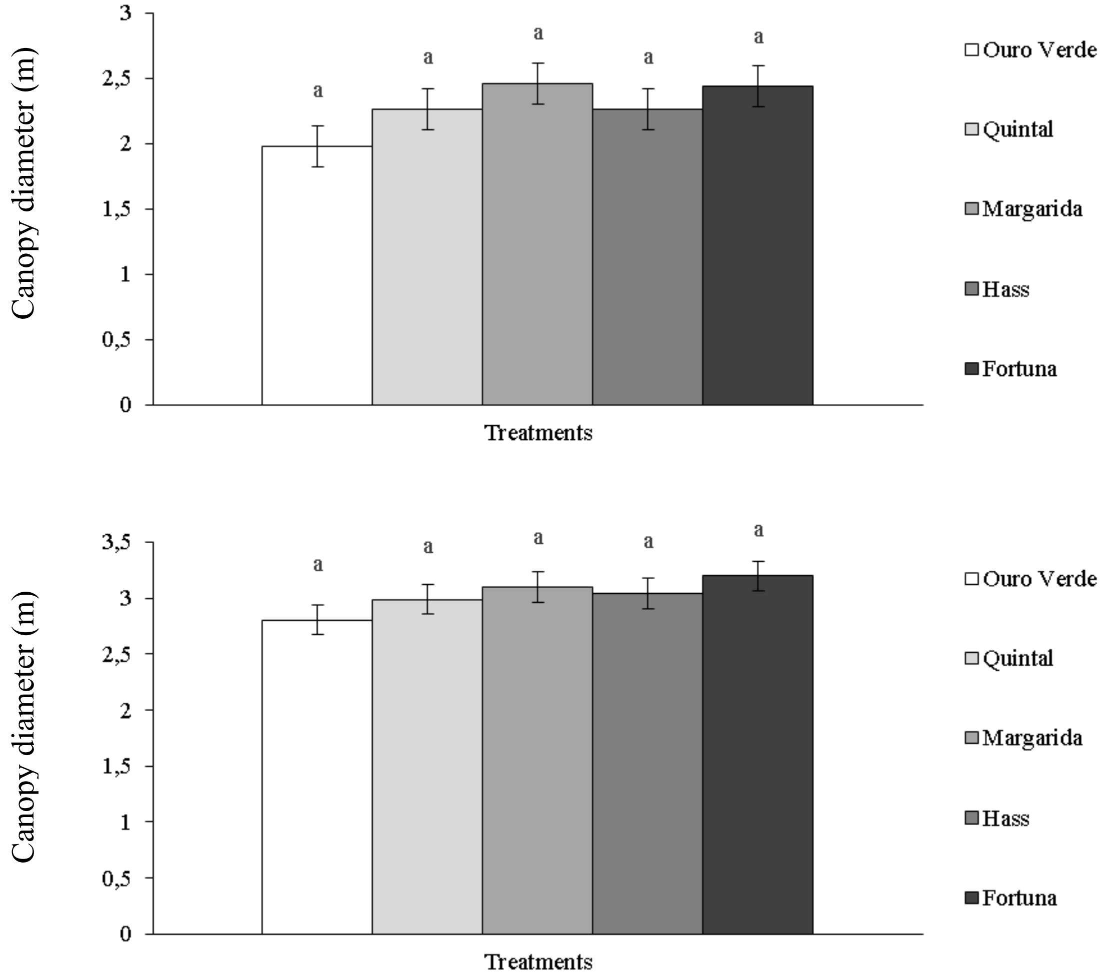
FIGURE 2 – Heights mean values of the different rootstocks in the Alto Paranaíba region in March 2021(A) and 2022(B).





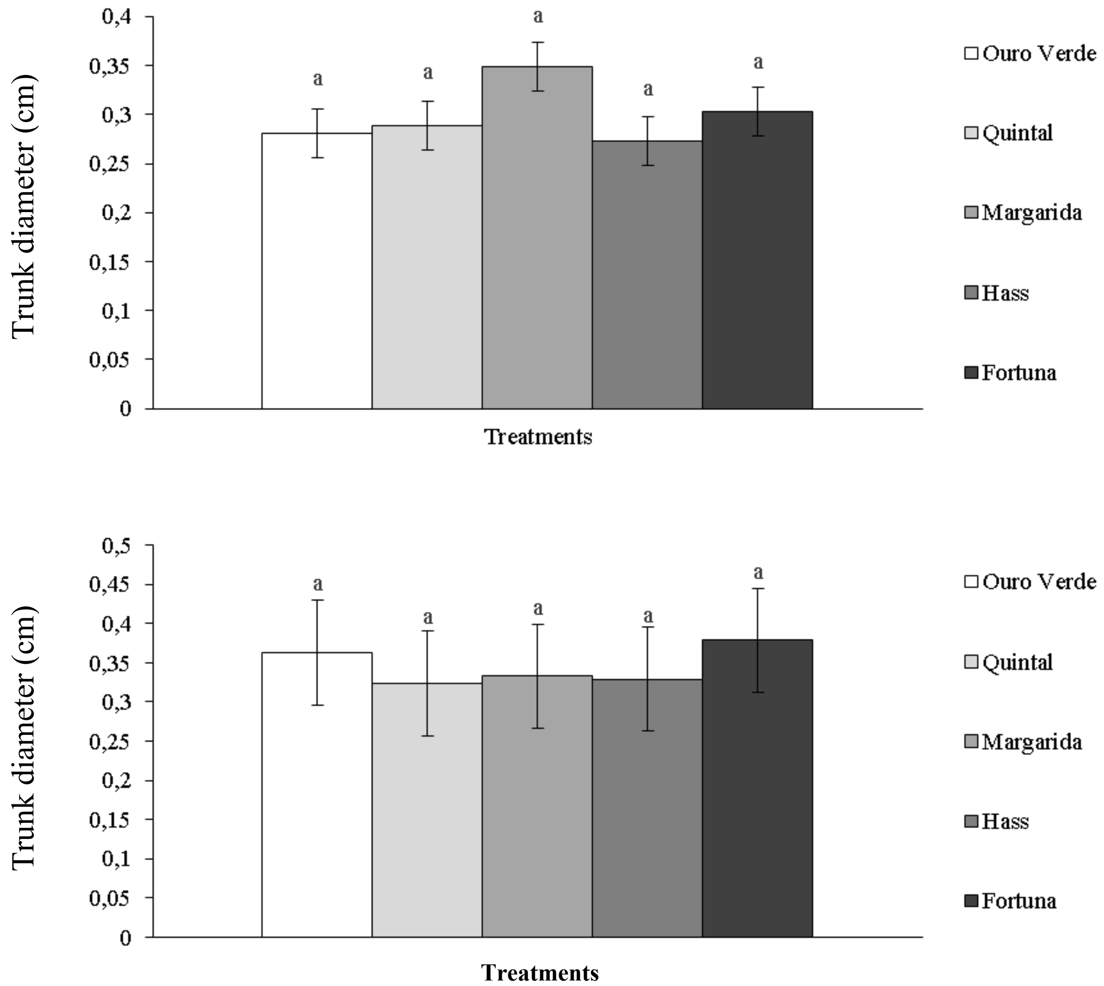
SNK test at 5% probability. Different letters indicate statistical differences.

FIGURE 3 – Canopy diameter of the different rootstocks in the Alto Paranaíba region in March 2021(A) and 2022(B).



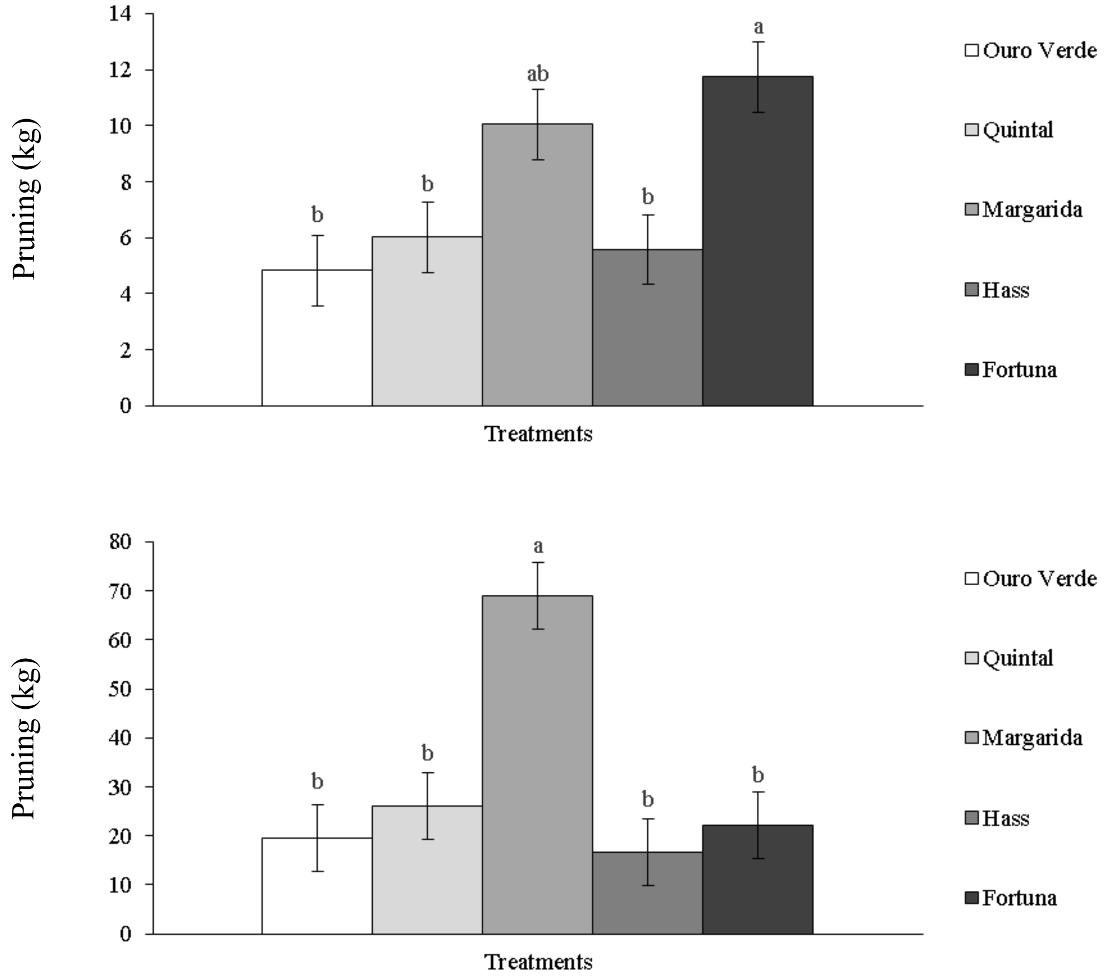
SNK test at 5% probability. Different letters indicate statistical differences.

FIGURE 4 – Trunk diameter of the different rootstocks in the Alto Paranaíba region in March 2021(A) and 2022(B).



SNK test at 5% probability. Different letters indicate statistical differences.

FIGURE 5 – Pruning of the different rootstocks in the Alto Paranaíba region in March 2021 and 2022.



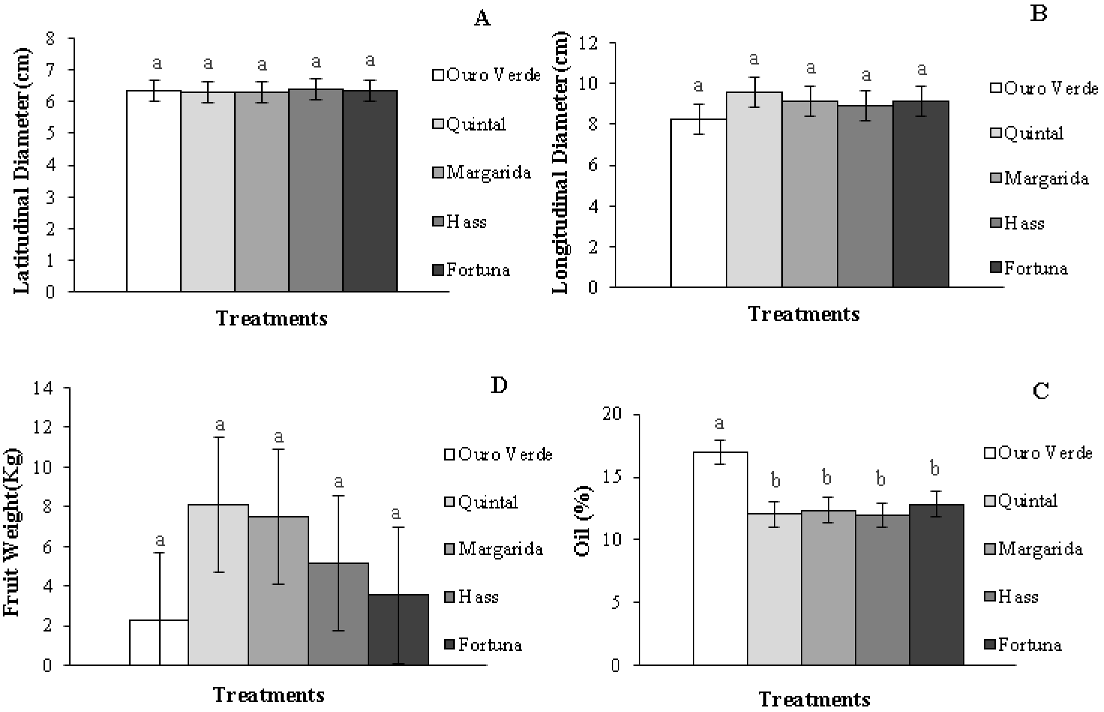
SNK test at 5% probability. Different letters indicate statistical differences.

The highest pruning values presented by the Margarida and Fortuna cultivars are related to the larger size of these tropical varieties grown in Brazil. Martins (2011) shows that Fortuna and Margarida are very close genetically, justifying the two rootstocks' similar behavior. Both are an Antillean and Guatemalan hybrid and are two cultivars well known for their high vegetative growth, in addition to presenting good disease resistance and excellent productivity. However, this high vegetative capacity is not attractive since they produce higher costs with pruning, and larger varieties make harvesting difficult.

Fruit production and quality

When evaluating the production and fruit quality parameters in 2021, no significant difference was found between treatments for longitudinal diameter, latitudinal diameter, and fruit weight. Regarding the oil percentage, the Ouro Verde variety had higher values than the other treatments (Figure 6).

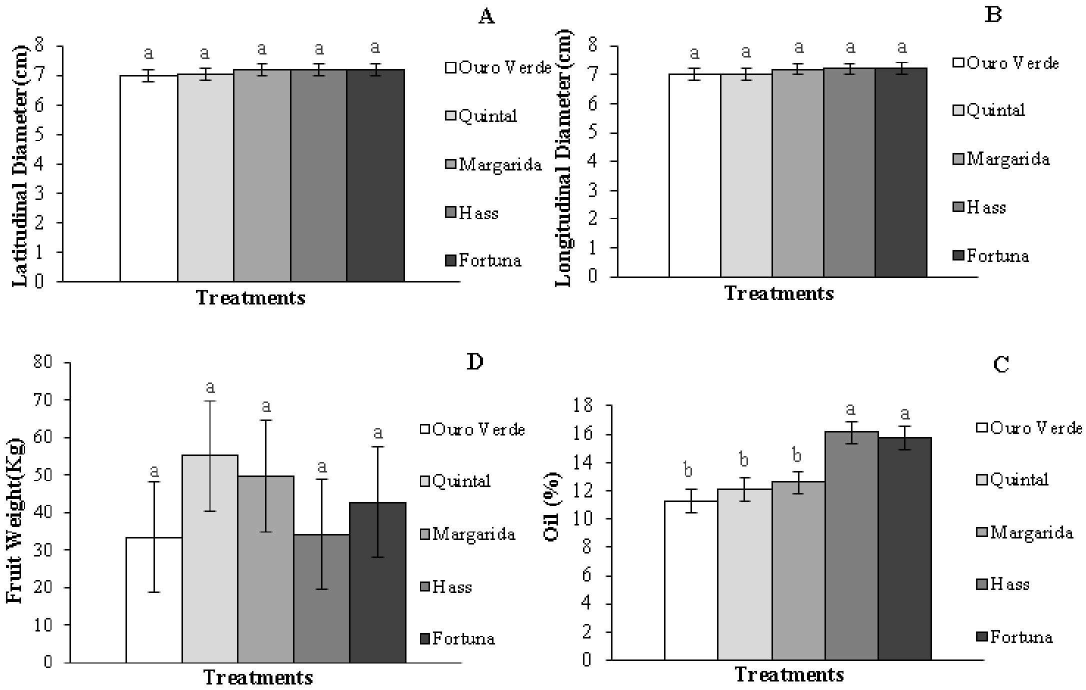
FIGURE 6 – Latitudinal diameter mean values (A), longitudinal diameter (B), and oil content (C) were used to evaluate the quality of fruit harvested in 2021.



SNK test at 5% probability. Different letters indicate statistical differences.

In the years 2022 and 2021, no significant difference was found between treatments for the variables analyzed except for the percentage of oil. The Hass and Fortuna showed higher values than the other treatments (Figure 7).

FIGURE 7 – Latitudinal diameter mean values (A), longitudinal diameter (B), and oil content (C) used to evaluate the quality of fruit harvested in 2022.



SNK test at 5% probability. Different letters indicate statistical differences.

The Ouro Verde cultivar showed a significantly higher oil percentage (Figure 6) when compared to the other treatments. Other works, such as Tango (2004), evaluating avocado different cultivars' lipid levels in fruits, showed that Ouro Verde has the highest oil content in the fruit, second only to Hass. This trait may have favored the lipids accumulation in the Hass canopy fruits grafted in Ouro Verde. However, the values observed in the second year showed higher lipids levels in the fruits of the Hass and Fortuna cultivar (Figure 7). The higher lipids values in the fruits of the Ouro Verde were possibly due to the cultivar productivity being about four times the smallest, allowing a more significant oil accumulation. It is essential to point out that high oil content in fruits also contributes to shorter shelf life. Therefore, to prove the facts, it would be necessary to carry out long-term studies to evaluate the lipid contents in the fruits over the years to determine possible rootstock's influence on the oil contents.

Physiological analysis

When evaluating the foliar pigment content parameters, a significant interaction was found between the rootstock cultivar and the evaluation period.

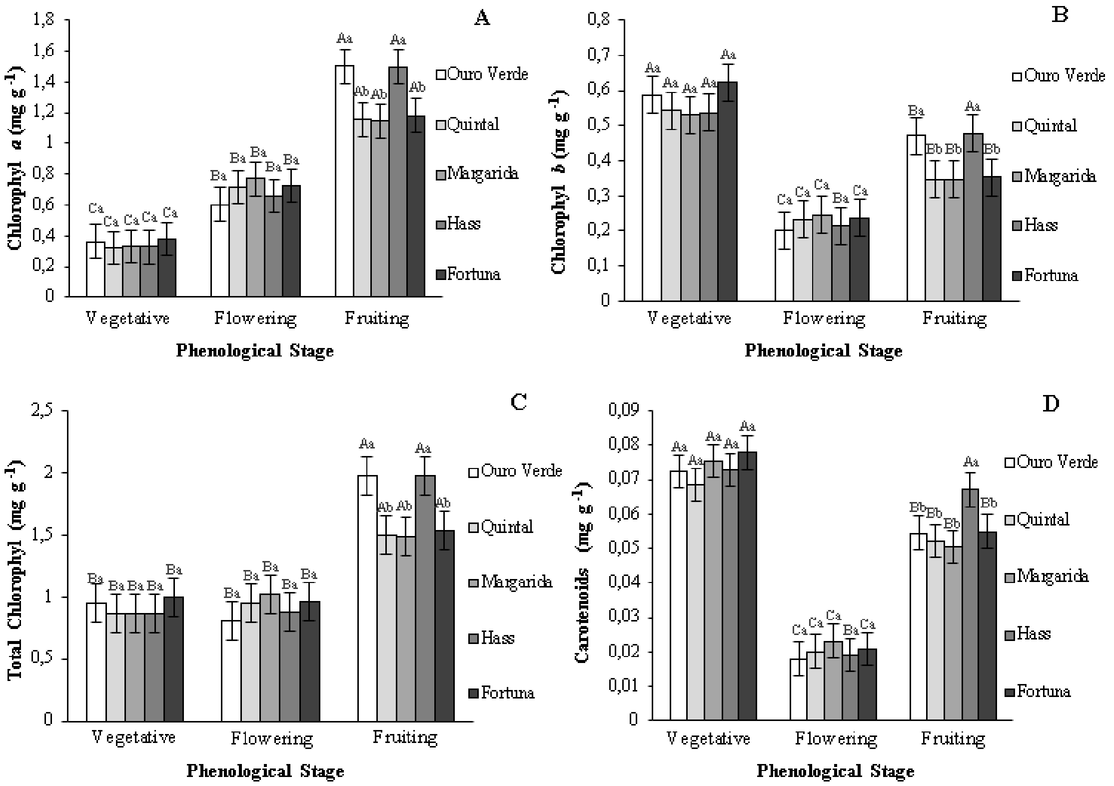
The chlorophyll *a* content increased over the seasons, without showing significant differences within the vegetative and flowering stages. However, within the fruiting stage, the

Ouro Verde and Hass cultivars expressed higher values (Figure 8). Chlorophyll *b* content was lower within the flowering stage, followed by the fruiting and vegetative stages, and an increase in chlorophyll *b* within the fruiting stage for the Ouro Verde and Hass cultivars.

When evaluating the total chlorophyll content, we did not observe differences for this variable in the Hass canopy, grafted with the different rootstocks, during the vegetative stage and flowering. During fruiting, in addition to expressing higher values than other phenological stages, the Ouro Verde and Hass cultivar increased the total chlorophyll content (Figure 8C).

The carotenoid content was higher in the vegetative stage without showing significant differences in fruiting for the Hass cultivar. However, the other cultivars showed increasing values between the flowering, fruiting, and vegetative stages (Figure 8D).

FIGURE 8 – Chlorophyll *a* mean value (A), chlorophyll *b* (B), total chlorophyll (C), and carotenoids (D) in avocado leaves at three collection times, vegetative, flowering, and fruiting.



SNK test at 5% probability. Capital letters (A) represent the comparison between times within each variety. Lowercase letters (a) describe the comparison between cultivars within each season.

The chlorophyll *a* content increased over time (Figure 8). The increase in this photosynthetic pigment can be explained due to the greater demand for photosynthesis for flowering and fruiting. The chlorophyll *a* quantity and carotenoids were inverse, excluding the photo-oxidation hypothesis by high irradiation. The chlorophyll and carotenoid contents should decrease together. This inverse relationship shows us a possible canopy adaptation when subjected to high irradiation. The increasing carotenoid contents are probably to avoid possible photo-oxidation.

The decrease of chlorophyll *b* (Figure 8) in similarity with the CO2 assimilation in the flowering period is related to the fact that the plant directs its photoassimilates to the reproductive parts, not their accumulation. It reduces its assimilation and chlorophyll *b* amount associated with the photosynthetic apparatus amplification for a broader spectrum of photons absorption.

Total chlorophyll contents were similar between vegetative and flowering and higher in the fruiting phase. This increase in chlorophylls in the fruiting phase can be explained by the fact that the plant needs a high photoassimilates amount to fill the fruits, thus requiring a stronger photosynthetic apparatus, since the higher the chlorophyll content in the leaf, the greater its photosynthetic capacity, and subsequent photo assimilates production.

When evaluating the gas exchange parameters (Figure 9), a significant interaction was found between the rootstock cultivar and the evaluation period only for the variable Internal CO2 concentration (Ci). Regarding the photosynthesis content (A), there was a significant difference between the treatments and the times of analysis, expressing lower values for the Quital cultivar. In contrast, the other cultivars did not show a significant difference. The flowering stage stood out for the low values presented among the seasons, directly related to lower temperatures (Figure 9A). There was no significant difference in the fruiting stage for cultivars.

The stomatal conductance (gs) contents were higher in the vegetative and fruiting stages, not showing significant differences between treatments, only between seasons. The flowering stage was evidenced again due to the lower values expressed.

When evaluating the internal CO2 concentration(Ci), a significant interaction was found between the rootstock cultivar and the evaluation period. All cultivars' inner concentration contents were similar between the vegetative and flowering stages. We observed that the lowest values were obtained in the fruiting stage. However, the Fortuna cultivar maintained values identical to the vegetative stage (Figure 9A).

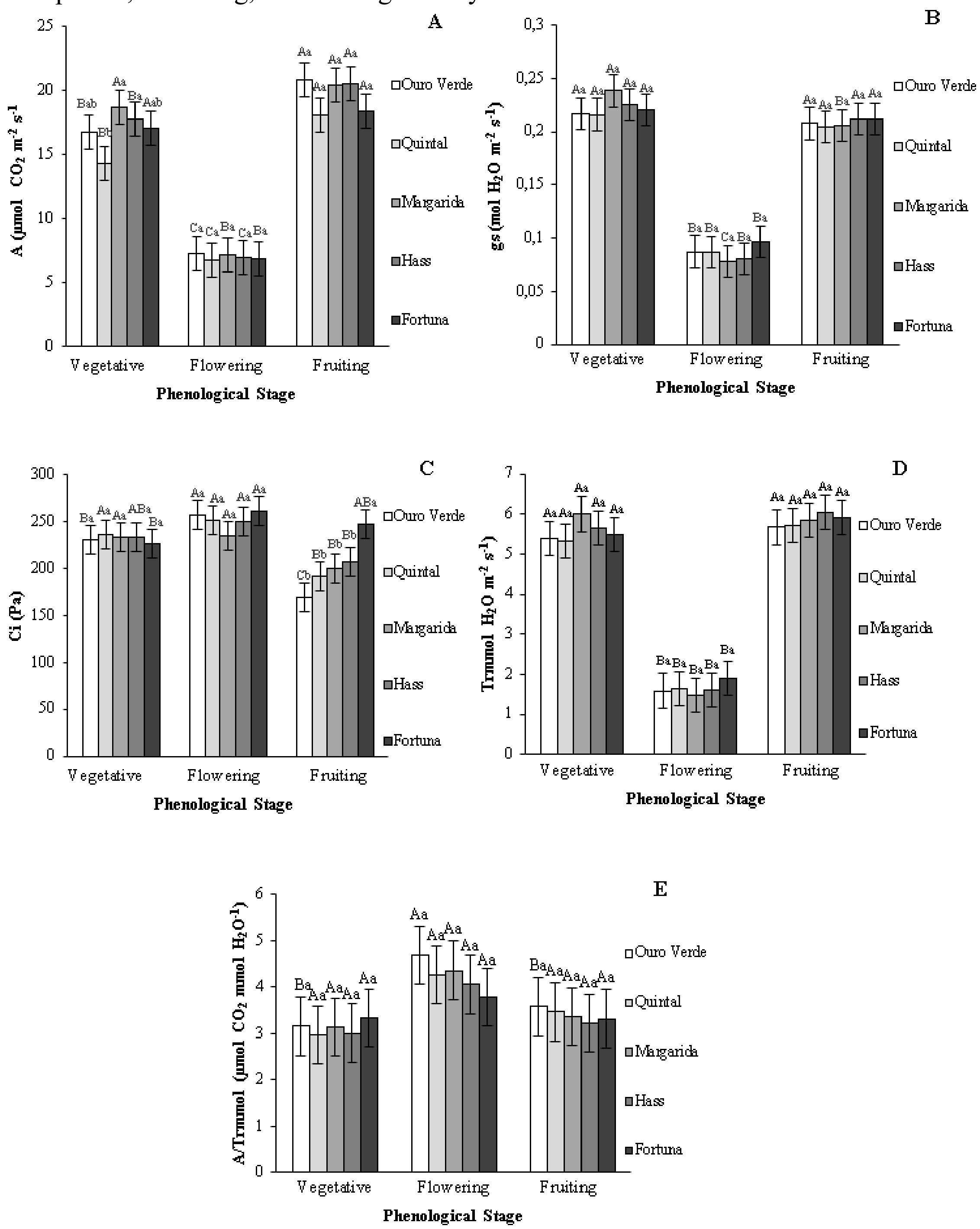
Transpiration (Trmmol) had no significant interaction between the rootstock cultivar and the evaluation period. There was a considerable difference between the stages, with higher values in the vegetative and fruiting (Figure 9D).

The water uses efficiency contents (A/Trmmol) did not find a significant interaction between the rootstock cultivar and the evaluation period. However, there was a substantial difference between the stages. The Ouro Verde cultivar was more efficient during the flowering stage. The other cultivars did not show significant seasonal differences (Figure 9E).

The CO2 assimilation values, stomatal conductance, and transpiration were similar (Figure 9), the highest values was observed in the vegetative and fruiting seasons, a result compatible with the hottest seasons of the year. According to Rossatto et al. (2010), tree species in full sun had better photosystem II efficiency and stomatal conductance, directly related to CO2 assimilation, which may explain their higher values during warmer periods.

The water use efficiency was higher during the flowering period, even when A and Trmmol values were lower in the same period (Figure 9E). This factor is related to the lower temperature evaluated at the time (Figure 1) since lower temperatures cause less transpiration, and consequently, the A/Trmmol ratio is higher. Therefore, the lower values demonstrated in the flowering period for the variables A, gs, and Trmmol are directly related to the lower temperature during this period, in addition to showing the adaptation of these plants to the climate since lower values of this trait, the Ci levels did not differ between phenological stages.

FIGURE 9 –Photosynthesis means values (A), stomatal conductance (B), internal CO2 concentration (C), Trmmol (D), and Water use efficiency (E) in three collection times, vegetative period, flowering, and fruiting in the year 2021.



SNK test at 5% probability. Capital letters (A) represent the comparison between times within each variety. Lowercase letters (a) describe the comparison between cultivars within each season.

The work shows an adaptation of the tropical rootstocks with the Hass canopy and better compatibility when using the same genetic material in the rootstock and top, Hass with Hass.

CONCLUSION

The cultivar Ouro Verde and Hass proved to be the most promising for use as a rootstock in the cerrado, as smaller plants, fruits with higher oil content, and better physiological parameters, such as carotenoids and chlorophylls, showing more remarkable adaptation to the environmental conditions.

Due to their high vegetative vigor, Fortuna and Margarida cultivars must be used with attention.

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3. SCIENTIFIC ARTICLE 2

Flowering and vegetative growth of avocado tree cultivated in Minas Gerais using paclobutrazol

ABSTRACT

The avocado tree has the habit of a humid forest plant; this characteristic influences the tendency to vigorous vegetative growth. This study evaluated the avocado's flowering and vegetative growth in the Alto Paranaíba region. It used paclobutrazol (PBZ), a growth regulator, to reduce its branch length, seeking a homogeneous flowering, avoiding drops in productivity. We also test a floral induction protocol using sulfates and nitrates and drop of fruits practice. It is a well-known and researched protocol with good scientific and technological bases for mangos in other cerrado areas in Minas Gerais. It could overcome some problems faced by farmers of avocados in the region if well investigated. Four experiments were conducted in two different locations. All experiments were designed to analyze twenty branches per plant divided into four quadrants. The number of plants in each experiment was chosen according to the usable experimental area given by the company. It was possible to study the avocado plant cultivated in eight different doses of paclobutrazol, 0,0; 0,5; 0,25; 0,75; 0,85; 1,0; 2,0 and 3,0 $g.m^{-1}$, with two different application ways, soil and foliar, in four application months, December 2021, March, May, and June 2022. The evaluations were made days after PBZ applying, during flowering, and during fruit set. It evaluated shoot length, panicle number and type, and fruit number. Paclobutrazol could reduce the shoot length in all application ways; the product also improves the plant's total flowers and determinate panicles number, possibly leading to more fruits.

Keywords - *Persea americana* Mill. PBZ. Shoot Length. Panicles.

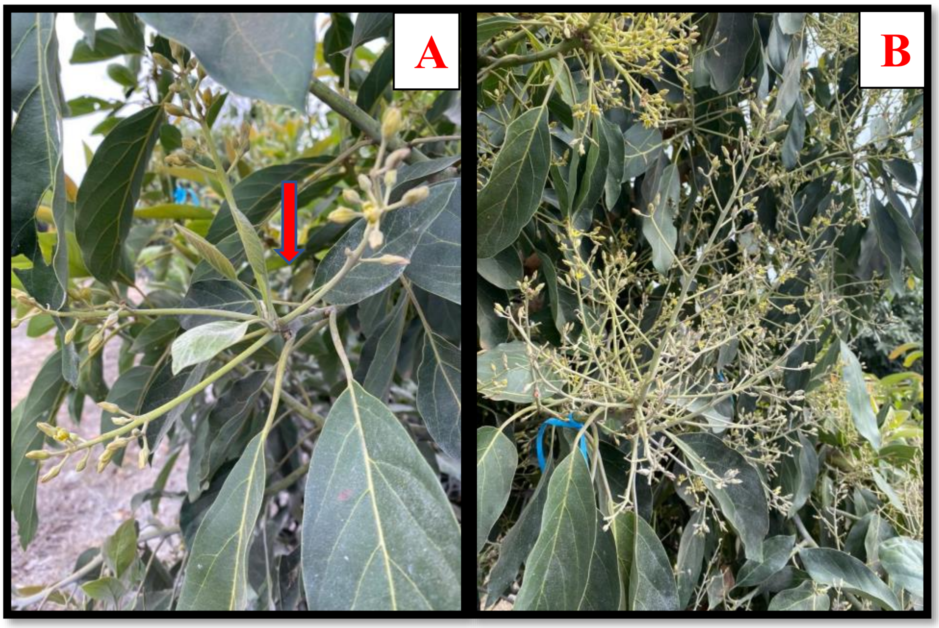
INTRODUCTION

Due to its origins in Central America and Mexico, the avocado tree has the habit of a humid forest plant. This characteristic influences the tendency to vigorous vegetative growth. This vegetative vigor results in two significant problems for producers worldwide; the first is related to the size of the plants, which ends up closing the orchard after four to five years of planting, making cultural treatments difficult, such as spraying and harvesting (MOUCO, 2008). A second problem is related to competition for photo-assimilated compounds, nutrients, and water between reproductive (panicles), vegetative (new shoots), and fruit when they coincide, leading to a reduction in fruit formation (WOLSTENHOLME, 1990).

A third problem comes up for producers in the Alto Paranaíba region, state Minas Gerais, related to hail rain and a large volume of rain during the fruit formation; added to that, the plants have a natural fall of fruits in November and December. This fact, hail rain, and natural drops cause a loss in productivity. Plants with uneven flowering, such as avocado, are likelier to lose fruits as they have fewer flowers for fruit set. This problem could be minimized if we could manage a better flowering using paclobutrazol some months earlier. Thus, due to the factors mentioned, avocado cultivated in warmer areas, as is the case in many regions of Brazil, is below 10 t/ha. This climatic condition encourages vegetative sprouting, disturbing the synchrony of the bloom.

A series of experiments were carried out using foliar sprays of growth regulators (WHILEY, 1992; CANTUARIAS-AVILÉS, 2016; DUARTE, 2018, BROGIO, 2018). With the experiments, it is possible to realize that avocado is responsive to gibberellin inhibitors, such as paclobutrazol (PBZ) and uniconazole, as they can reduce the vegetative growth of these plants (KÖHNE, 1987). Most experiments were carried out with applications of growth regulators to reduce the shoot growth of indeterminate panicles (Figure 1), which occur naturally in the avocado tree, to reduce the competition of the vegetative drain that develops in flowers (ADATO, 1990).

FIGURE 1 – Avocado indeterminate panicle, vegetative growth in the middle (A), avocado determinate panicle (B).



As seen in other crops, the effects of paclobutrazol applications in the soil to promote flowering still need to be better understood in avocado plants. PBZ seems to be a potential product to reduce biennial production and uneven flowering, which is very common in avocado orchards.

The application of paclobutrazol (PBZ) to plants can have different objectives depending on the crop type and the producer's purpose. In some crops, the application of PBZ in December can help induce flowering and production of off-season fruits, as seen by many authors.

However, it is essential to remember that the application of PBZ should be deeply studied as it needs to be done with caution and following the appropriate instructions. The improper use or excessive amounts can adversely affect the quality of the fruits produced and present environmental and health risks. Several doses were tested in plants of different ages, even in the formation of the orchard, to finally have a complete analysis of the effects and possibilities of this product on avocado.

This work intends to show the first year of analysis of all experiments carried out with the cultivation of avocado with PBZ in Minas Gerais in the Alto Paranaíba region, based on the floral induction technique used in plants (OLIVEIRA, 2020; SHENG FAN, 2018; MANDAL 2014, MOUCO, 2005). This work can also be used as a base for further experiments.

MATERIAL AND METHODS

The commercial products used were Cultar 250 ® in Tsuge Group farms and PacloBR ® in Avocado Milênio farm; both have 25% of paclobutrazol. All orchards were irrigated. The article aims to evaluate all the experiments using paclobutrazol in the avocado cycle in Alto Paranaiba. Four tests were conducted to manage the flowering and the vegetative growth of the avocado cultivar Hass.

The application of PBZ was made at different moments, allowing us to see the capacity of this triazole to promote a homogeneous flowering, reduce productivity losses, as we see in many crops (Tesfahun, 2018), and test its capacity to induce early fruits with later applications during the cycle as seen in mangos (Mouco,2005). For better understanding, the methodology and results were divided into topics.

First experiment

The first experiment was designed in a 5-years-old commercial avocado orchard in a 7x6 m spacing, belonging to the Tsuge Group in the Rio Paranaíba city - Minas Gerais, Brazil, with the coordinates of 19° 25' 33" S and 46° 15' 37" W with an altitude of 1,180 m. According to the KÖPPEN classification, the region climate is Cwa type, with an annual minimum temperature of 11.0 ℃, an average annual temperature of 21.1 ℃, and an average yearly maximum temperature of 22.3 ℃ and a total annual precipitation of 2,713.65 mm (PIRES; YAMANISH, 2014).

Five treatments were used, represented by different PBZ doses applied on December 2, a control treatment, and additionally, a treatment with PBZ and all the late fruits harvested, and three blocks to reduce the environmental effect. In each block, we had three plants, nine plants for each treatment, totaling 45 in the whole experiment, all grafted with the cultivar Hass. The shoot length was analyzed 60 days after PBZ application, and the number of panicles during flowering.

- Treatment 1 (T1): 0,25 per meter canopy radius ($g.m^{-1}$), no late fruits harvest.
- Treatment 2 (T2): 0,50 ($g.m^{-1}$), no late fruits harvest.
- Treatment 3 (T3): 0,75 ($g.m^{-1}$), no late fruit harvest.
- Treatment 4 (T4): 0,50 ($g.m^{-1}$), all late fruits harvest to enhance a late flowering.
- Control treatment (T0): 0,0 ($g.m^{-1}$), without intervention.

Second experiment

The second experiment was done on the same farm belonging to the Tsuge group with the same cultivar Hass, with the PBZ application on March 26. It was conducted in a 12.0-hectare area, 7x6 m spacing, in a 2-year-old commercial avocado orchard. Thus, the experiment was designed in randomized blocks, and 30 plants were selected, distributed in five treatments, six plants for each treatment, divided into three blocks. In addition to reducing gibberellin through PBZ, 45 days after using the product, we applied sulfate of potassium (3%) and ethephon foliar directly on the branches on the following dates: 05/10/2022, 05/17/2022, 05/24/2022, 05/31/2022. The last application was added with Ethrel 240 in the dosage of 50 ml of the product in 100 L of water, an amount with no effect on leaf fall, just enough to promote branch maturation. Seventy-two days after PBZ application, 06/06/2022, 06/13/2022, 06/20/2022, 06/27/2022, 07/04/2022, and 07/14/2022 to help bud sprouting and breaking dormancy potassium nitrate (2%) was applied.

- Treatment 1(T1): 0,85 ($g.m^{-1}$), with sulfate and nitrate application.
- Treatment 2 (T2): paclobutrazol applied foliar with Arbus implement, 20L of Cultar (250C) in a 2000L tank (1%), sulfate, and nitrate application.
- Treatment 3 (T3): 1,0 ($g.m^{-1}$), with sulfate and nitrate.
- Treatment 4 (T4); 0,0 ($g.m^{-1}$), only sulfate and nitrate application.
- Control treatment (T0); with 0,0 ($g.m^{-1}$) without sulfate and nitrate.

This experiment was analyzed shoot length 60 days after PBZ application, flowering, fruiting, and second vegetative growth during fruit formation.

Third experiment

The third experiment used PBZ and floral induction protocol (vegetal regulator + minerals to help mature branches and bud sprout + harvest of delayed fruits) in a 4-year-old commercial avocado orchard, 7x6 m spacing on the Tsuge group's farm with Hass cultivar. However, this time, the application was made on May 20, after the area was harvested, providing, with the same idea of the second experiment, applications of potassium sulfate (3%) and ethephon foliar directly on the branches on the following dates: 07/14/2022, 07/19/2022, and 07/26/2022, 54 days after paclobutrazol application. Ninety-two days after the PBZ application, on 22/08/2022, 29/08/2022, and 05/09/2022, potassium nitrate (2%) was applied.

Four treatments were allocated in three blocks; nine plants per treatment were used, totaling 36 plants.

- Treatment 1 (T1): 1,0 ($g.m^{-1}$), complete floral induction protocol.
- Treatment 2 (T2): 2,0 ($g.m^{-1}$), complete floral induction protocol.
- Treatment 3 (T3): 3,0 ($g.m^{-1}$), complete floral induction protocol.
- Control treatment (T0): no intervention.

The experiment evaluated shoot length 60 days after PBZ application, flowering, fruiting, and second vegetative growth during fruit formation.

Fourth experiment

With the PBZ application on June 22, the fourth experiment was carried out on another farm, Avocados Milenio, located in Ibiá, Minas Gerais, Brazil, 19° 29′ 4″ S, 46° 32′ 51″ W, 914 with an altitude of 914m, tropical climate with a dry season, Köppen-Geiger climate classification: Cwa. Throughout the year, in general, the temperature varies from 14 °C to 30 °C and is rarely below 11 °C or above 34 °C.

A 5-year-old commercial avocado orchard was used, with dense planting, 6,0x3,5 m spacing. The experiment was conducted with the same canopy cultivar, Hass, using designed randomized blocks with three PBZ doses and a control treatment, distributed in three blocks with four plants in each block, totaling 48 plants.

- Treatment 1 (T1): 1,0 ($g.m^{-1}$)
- Treatment 2 (T2): 2,0 ($g.m^{-1}$)
- Treatment 3 (T3): 3,0 ($g.m^{-1}$)
- Control treatment (T0): without intervention.

In this experiment, all treatments kept the fruits, and for this time of application, sulfates and nitrates were unnecessary, as the branches were already mature and buds sprouting. The same parameters were evaluated.

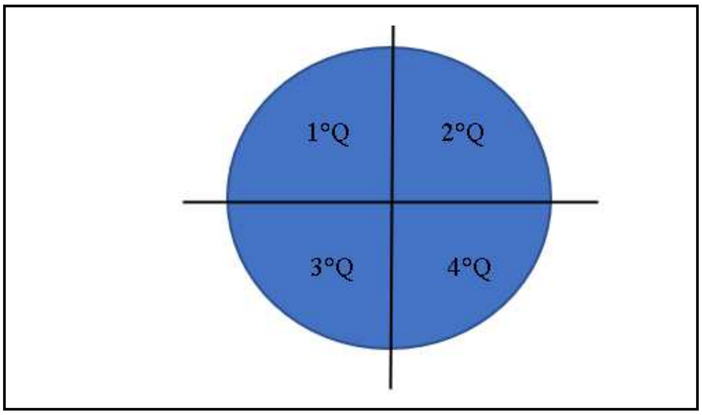
General traits

In the first month of each experiment, the plants selected from all experiments were divided into quadrants (Figure 2). Five branches were marked in each quadrant totaling twenty branches per plant; stems were chosen in a standard way for all plants before flowering, good conditions leave, with more than four buds visible in the branches leaf axils, and without flowers.

In both farms, the avocado tree culture was managed through soil analysis and IPM, using organ mineral compounds to replace nutrients and biological and chemical control to reduce pests. Pruning is concentrated in March.

The evaluations were made in all marked branches, approximately 700 branches per experiment; vegetative growth was evaluated sixty days after PBZ application with a tape measure. During full flowering, when more than 50% of the plants have panicles, the number of panicles per marked branch and type of panicle emitted was manually counted, as well as the number of fruits when forming. We also measured the second shoot length of the indeterminate panicles after its expansion, named Second growth.

FIGURE 2 – Division of quadrants to select and evaluate the tree branches.



The PBZ, applied via soil, was diluted in 2L of water following the dates and treatments established. PBZ was applied running down the plant trunk. For soil application, a linear canopy meter was used to measure the doses; that is, with a measuring tape, both canopy directions were evaluated. Thus, the average diameter was used to measure the value of active ingredient applied per meter canopy radius ($g.m^{-1}$).

The observed averages were submitted to statistical analysis through the Dunnett test, compared treatments to control treatments and the SNK test, comparing qualitative traits and regression for the doses with the SPEED Stat v2.8 software (CARVALHO, 2020).

RESULTS AND DISCUSSION

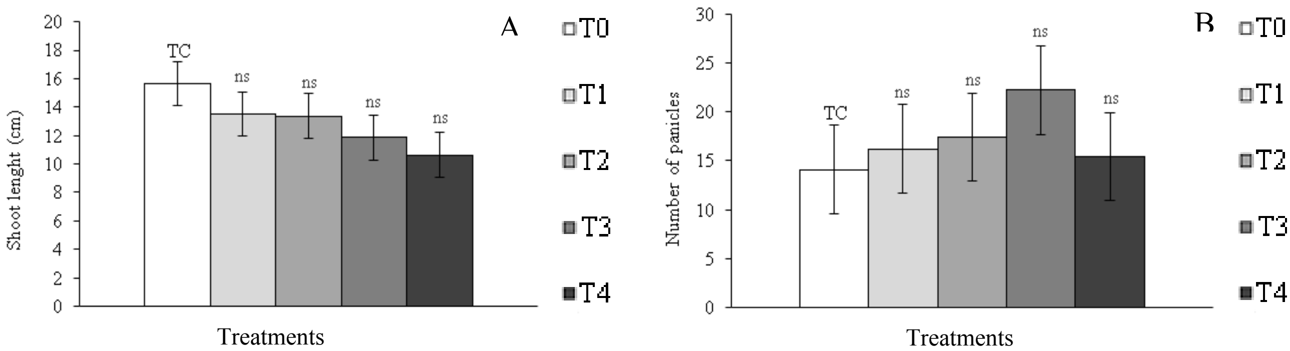
Paclobutrazol has been studied with significant effects in many plants with different applications (DESTA, 2021). The results we achieved in this work are the first vision of what this technique can improve in avocado cultivation. Continuing these studies is necessary to leverage and establish a new technology for avocado farmers. None of the treatments could anticipate the floriation; all the plants subjected to PBZ had their full flowering approximately in the middle of September.

First experiment (Tsuge Group crop)

The first experiment targeted the shoots that did not flower in the flowering period after winter, a fact that occurs due to the uneven flowering in the region, which can make possible late flowering and early fruits in the following year. This first experiment also tested the PBZ sensitivity applied to the soil, data found in a few experiments and none in the Alto Paranaíba region. The doses used do not promote flowering in the following months.

This experiment shows that avocado has a sensibility to more significant PBZ doses, mainly if it is applied intended to late flower. The product did not affect the plants for all traits analyzed compared to the control (Figure 3). The doses used were low and had no effect on the applied date, unlike mango, which is affected by doses less than 1,0 ($g.m^{-1}$), as seen by Oliveira 2020.

FIGURE 3 – A- The shoot length in different treatments, B - Panicles number branch of avocados Hass treated with PBZ ($g.m^{-1}$), in December 2021.



The averages with ns do not differ from the control treatment (TC) at the 5% probability level by the Dunnett test.

T0: Control T1: 0,25 $g.m^{-1}$ T2:0,50 $g.m^{-1}$ T3: 0,75 T4: 0,5 $g.m^{-1}$ + late fruits harvest.

Second Experiment (Tsuge Group crop)

For better comprehension, the following experiments had their results divided into Vegetative growth, always analyzed before the first flowers appear. Flowering; separated into indeterminate panicles, determinate panicles, and total panicles and Second growth; evaluated days after anthesis and fruiting.

Vegetative growth

The first thing we see in this experiment is that high doses start to take effect on plants; this experiment was carried out in two years old, shorter plants, which could have potentiated this effect. The treatment only with sulfate and nitrate application did not affect vegetative growth and behavior as a control treatment for all traits; as seen by Oliveira 2020 and Martinez 2020 for mango, treatments only with minerals do not affect flowering.

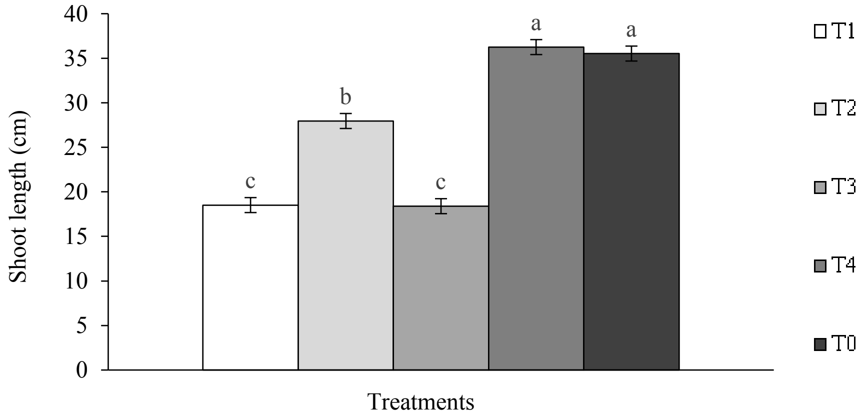
The application of sulfates and ethephon stimulates the maturation of the branches in many fructiferous plants, assisting in the accumulation of carbohydrates that are a source of energy for floral initiation. In addition, it is a signal for the change from vegetative to reproductive activity. The potassium ion can interfere with the potassium/nitrogen ratio, preventing vegetative growth and collaborating with maturation.

The application of nitrate salts breaks bud dormancy, the first flowering event, favoring flowering uniformity and increasing the number of panicles. This fact occurs due to nitrate inducing the activity of the enzyme nitrate reductase, which triggers the synthesis of methionine, an amino acid precursor of ethylene, and stimulates floral differentiation in physiologically mature branches. Despite this, the reduction of gibberellin levels seems crucial in floral induction. This fact does not occur in treatments without PBZ, T0, and T4 as seen in several works already cited.

Foliar treatments had an effect but were slower than soil application. Treatments with PBZ in soil shortened the branches more efficiently (Figure 4). Foliar applications have no impact on mangos. In avocados, this practice had a good effect in reducing shoot length, probably because the product's contact with active leaves reduced endogenous gibberellins reducing the shoot length. The product in the soil has more contact time with the plant, and the molecule is mobile in the xylem through the transpiration flow, increasing its effectiveness in soil applications (Figure 4).

Paclobutrazol reduces the synthesis of gibberellin, as it interferes in the first three steps of the synthesis, inhibiting kaurene oxidation and preventing the formation of ent-kaurenol, ent-kaurenal and acid - entcaurene. These reactions are catalyzed by the enzyme kaurene oxidase, which is inhibited by the action of triazoles, thereby reducing the amount of endogenous gibberellins in the branches.

FIGURE 4 – Shoot length of avocados Hass sixty days after being treated with PBZ in March 2022.



Different letters indicate statistical differences (SNK $P \leq 0.05$).

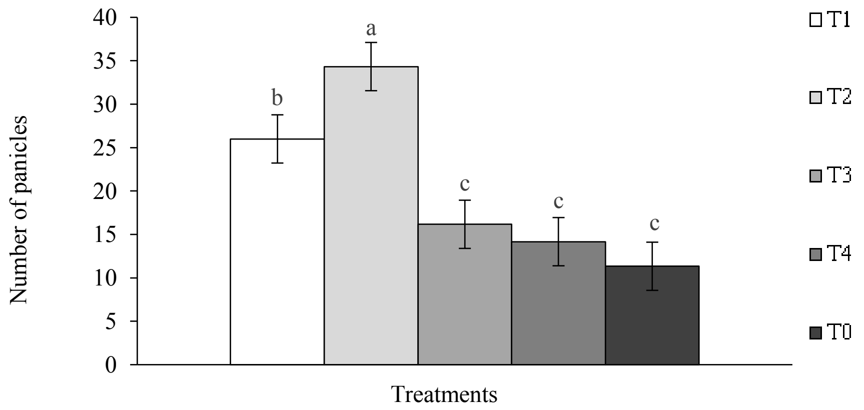
T0: Control T1: 0,85 $g.m^{-1}$ T2:Foliar (1%) T3: 1,00 $g.m^{-1}$ T4: 0,0$g.m^{-1}$Only Nitrates and Sulfates

Flowering

Indeterminate panicles

The number of indeterminate panicles in the branches was more significant in 0,85, and foliar application, treatment with 1,0g, does not differ from the control treatment (Figure 5), probably because of the effect in determinate panicles (Figure 6).

FIGURE 5 – Number of avocados Hass indeterminate panicles treated with PBZ in March 2022.



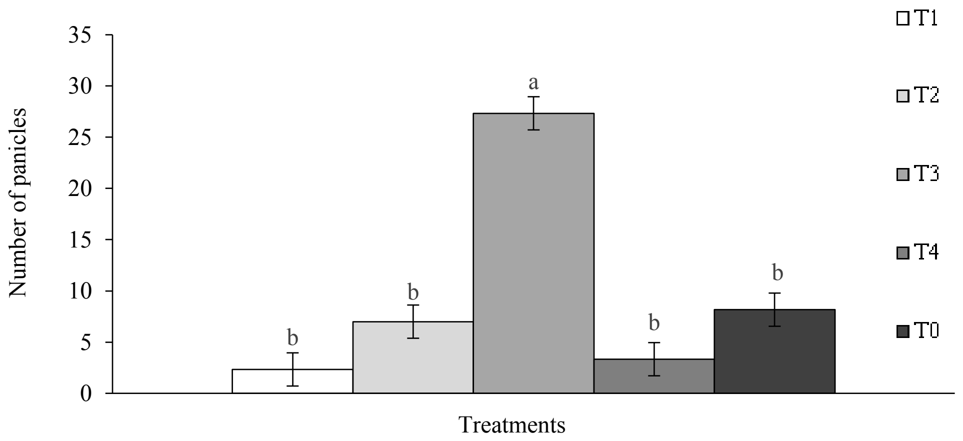
Different letters indicate statistical differences (SNK $P \leq 0.05$).

T0: Control T1: 0,85 $g.m^{-1}$ T2:Foliar (1%) T3: 1,00 $g.m^{-1}$ T4: 0,0$g.m^{-1}$Only Nitrates and Sulfates

Determinate panicles

The determinate panicle number differed from the control only for doses of 1,0 g.m-1, which is probably explained by the product's effect on these panicles. Before panicle emission, the gibberellin reduction in the branches is one of the factors determining its development. The use of PBZ reduced gibberellins inducing determined panicles. These results suggest a possible induction of buds in periods different from those in other producing regions. As mango shows, paclobutrazol can induce panicle pruning instead of vegetative shoots. Its effect is not entirely understood, but in scientific literature, paclobutrazol can induce even flowering genes in plants (FT gene) (POKAWATTANA, 2018; ZHANG, 2016). As well as mango plants, PBZ applications increase the number of determinate and total panicles (Figures 6 and 7) (CHUSRI, 2008).

FIGURE 6 – Number of determinate panicles of avocados Hass treated with PBZ in March 2022.



Different letters indicate statistical differences (SNK $P \leq 0.05$).

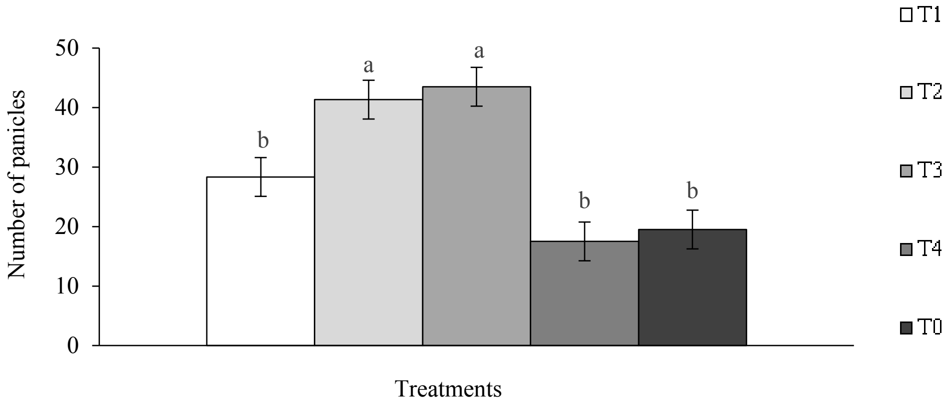
T0: Control T1: 0,85 g.m^{-1} T2:Foliar (1%) T3: 1,00 g.m^{-1} T4: 0,0g.m^{-1}Only Nitrates and Sulfates

:

Total panicles

For the total panicles number, only Foliar applications and doses of 1,0 g.m^{-1} differed from the control treatments (Figure 6). The avocado seems more responsive with more PBZ quantity to achieve effects in total panicles, as seen by Mouco 2005 for mangos. Smaller doses had no effect in some cultivars.

FIGURE 7 – Number of total panicles of avocado plants treated with PBZ in March 2022.



Different letters indicate statistical differences (SNK $P \leq 0.05$).

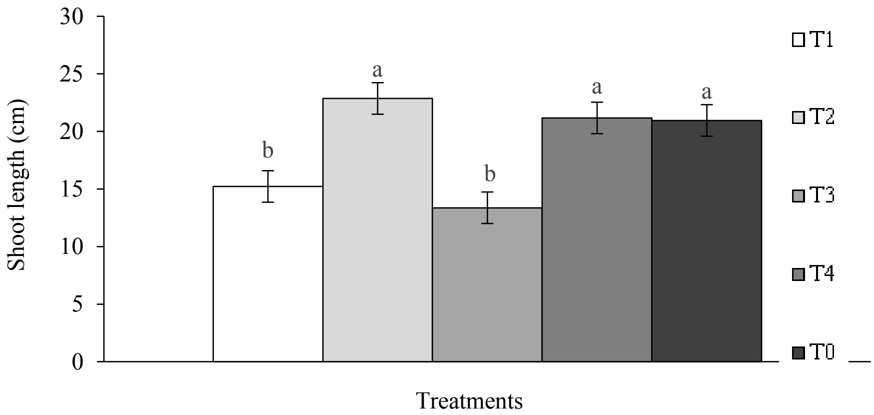
T0: Control T1: 0,85 g.m^{-1} T2:Foliar (1%) T3: 1,00 g.m^{-1} T4: 0,0g.m^{-1}Only Nitrates and Sulfates

:

Second growth

This trait shows the effect of the product even after flowering (Figure 8). It is one of the most significant discoveries in an attempt to improve the fruit set; the product efficiently reduced the vegetative shoot of indeterminate panicles. Wolstenholme (1990) shows that this reduction can reduce the number of natural fruits dropping. Only soil application presented reductions in indeterminate panicle growth (Figure 8), which can be explained by this product's interaction with the soil. It is already known that application via soil is efficient due to the high stability of the product in the ground, leaving it available to be absorbed by plants for a longer time (SIQUEIRA E SALOMÃO 2002). According to Costa et al. (2008), PBZ has a low sorption potential (Kd= 0.83 L Kg^{-1}), showing potential for mobility in the soil, with 43.7% of the applied PBZ being transported beyond the first 10 cm of soil depth. Most of the avocado roots are at this profundity.

FIGURE 8 – Shoot length of indeterminate panicles of avocados plants treated with PBZ in March 2022.



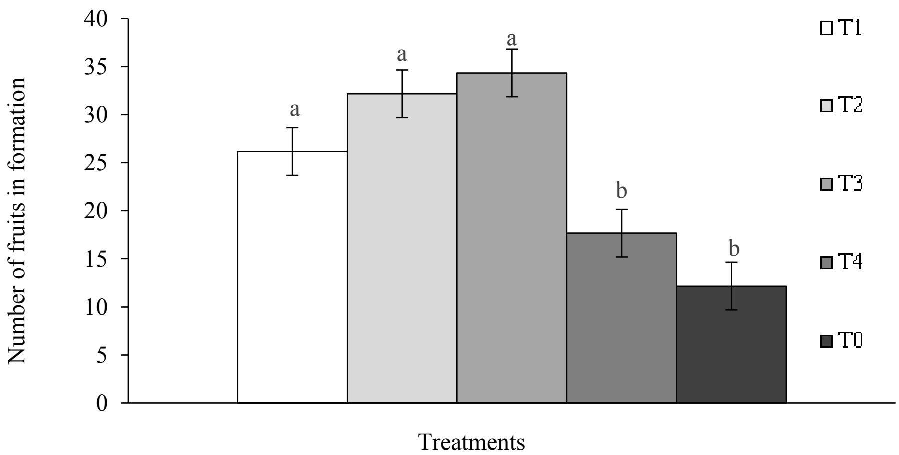
Different letters indicate statistical differences (SNK $P \leq 0.05$).

T0: Control T1: 0,85 $g.m^{-1}$ T2:Foliar (1%) T3: 1,00 $g.m^{-1}$ T4: 0,0$g.m^{-1}$Only Nitrates and Sulfates

Fruiting

Although the number of determinate panicles differed from the control treatment only for doses of 1,0g, the number of fruits had improved for all treatments using PBZ (Figure 9), probably because of its effect on standardizing the flowering and improving the fruit set in general. PBZ can reduce the length of the branches, indicating a reduction of endogenous gibberellin, allowing the panicle formation and not another vegetative branch. The appearance of panicles in most branches leads to greater probability in the formation and setting of fruits.

FIGURE 9 – Number of fruits in formation of avocados plants treated with PBZ in March 2022.



Different letters indicate statistical differences (SNK $P \leq 0.05$).

T0: Control T1: 0,85 $g.m^{-1}$ T2:Foliar (1%) T3: 1,00 $g.m^{-1}$ T4: 0,0$g.m^{-1}$Only Nitrates and Sulfates

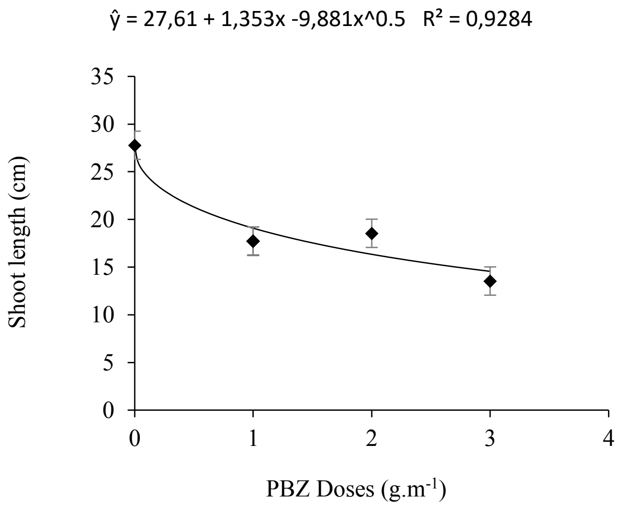
Third experiment (Tsuge Group crop)

Fruits removal that has not reached the ripening point to promote floral induction helps to reduce the gibberellins promoter's potential from the seeds, which can reduce flowering (GUARDIOLA, 1992). This experiment received all the floral induction protocols in its treatments, except for the control, dose 0. Using the protocol leads to more precise results with representative models to describe the traits evaluated.

Vegetative growth

Doses bigger than 0.85g.m^{-1} seems to affect the initial shoot length considerably. In model 1, we see the length of the shoots behavior as a root regression model with the shorter branches in the bigger doses, as seen by many authors in other cultures using the same product (AREDE, 2017; FRANÇA 2018; OLIVEIRA, 2022). This result proves the initial effect of the product.

Model 1 – Regression model for shoot length of avocado plants sixty days after treated with different doses of paclobutrazol applied in May 2022.

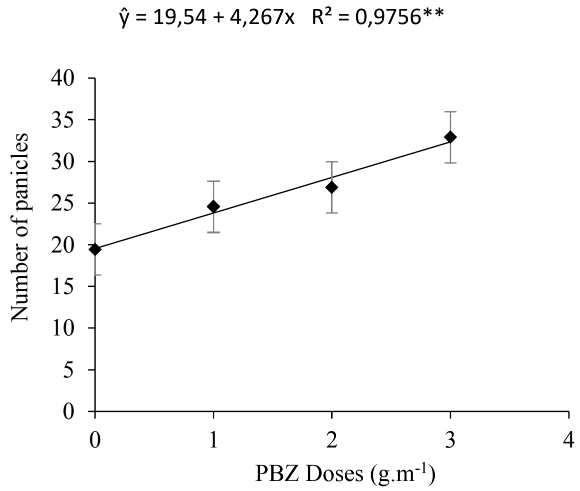


Flowering

Indeterminate panicles

The doses had a linear regression increasing the number of indeterminate panicles with increased quantities (Model 2). Shortening of shoots, indicating reduced endogenous gibberellin levels, may lead to increased panicle formation.

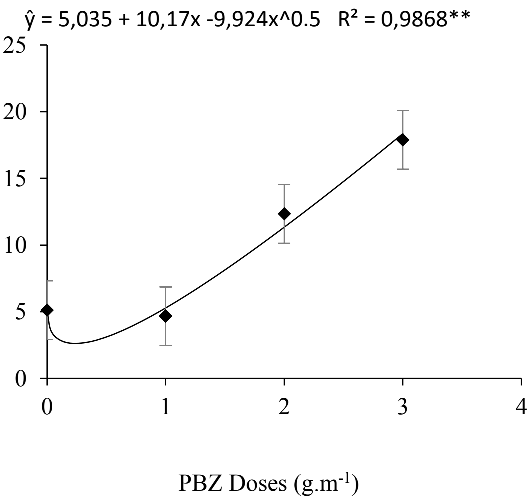
Model 2 – Regression model for indeterminate panicles of avocado plants treated with different doses of paclobutrazol applied in May 2022.



Determinate panicles

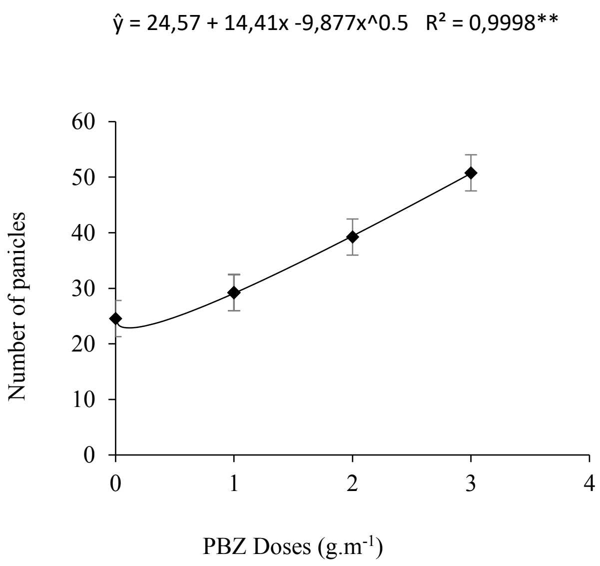
A root regression model was the best model for the determinate panicles per branch, the determinate panicles number achieved the maximum in the maximum doses (Model 3), and the same effect occurred to total panicles (Model 4).

Model 3 – Regression model for number of determinate panicles of avocado plants treated with different doses of paclobutrazol applied in May 2022.



<u>Total panicles</u>

Model 4 – Regression model for number of total panicles of avocado plants treated with different doses of paclobutrazol applied in May 2022.



Second growth

The indeterminate panicle growth, as well as in experiment 2, showed the potential of this product to reduce vegetative growth even months after product application. The doses followed a linear regression model with the shorter branches in bigger doses (Model 5). Figures 10 A and B illustrate the significant differences in shoot length from stems of plants treated with PBZ and control treatments.

Model 5 – Regression model for the second shoot length evaluation of avocado plants treated with different doses of paclobutrazol applied in May 2022.

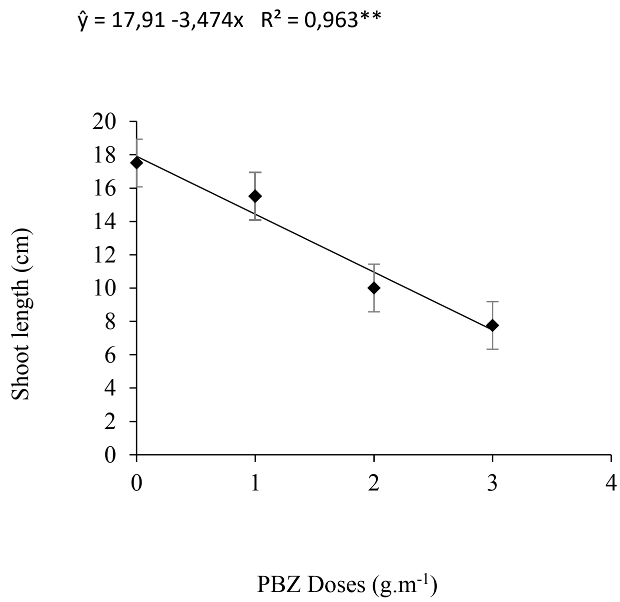
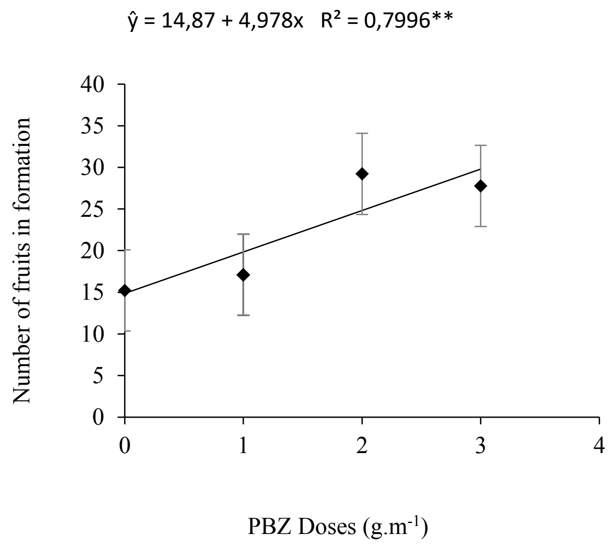


FIGURE 10 – Long vegetative growth of the branch after flowering in control treatments (A) and shorter shoots in plants with paclobutrazol (B).

Fruiting

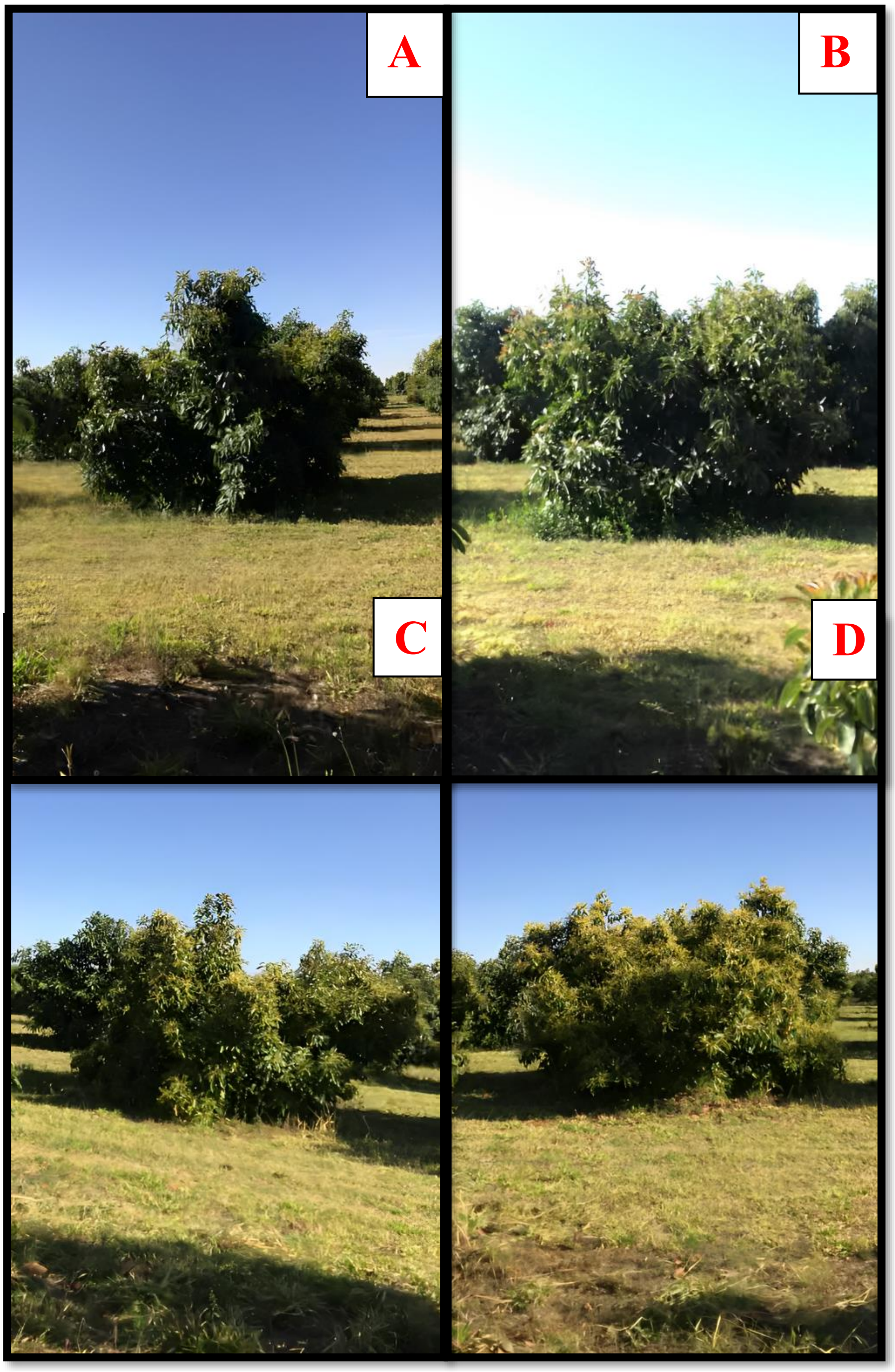
Fructification has behavior as a linear model for the doses (Model 6); where we had more fruits with more product, the fruit set improved as the number of flowers increased.

Model 6 – Regression model for number of fruits per branch of avocado plants treated with different doses of paclobutrazol applied in May 2022.



The reduction of shoot length, increases in flowering, and fruit set, with the application of PBZ on soil, were also observed by CHATZIVAGIANNIS et al. (2014), COELHO et al. (2014), OLIVEIRA (2020) in a wide cultivar of mangos. Figure 11 D shows the homogenous flowering in plants treated with 3,0g of paclobutrazol used on soil with applications on May 20. The results of this experiment show the efficiency of using the floral induction protocol in avocados grown in Alto Paranaiba.

FIGURE 11 – Avocado cultivated in different doses of paclobutrazol. A (0,0g) B (1,0g) C (2,0g) D (3,0g).



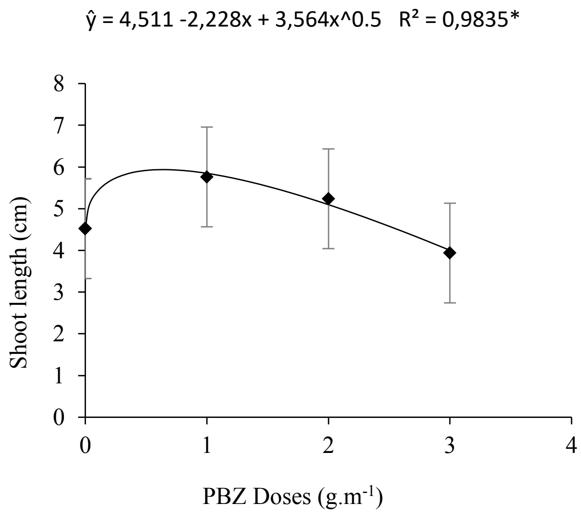
<u>Fourth Experiment (Avocado Milenio crop)</u>

The growth regulator application on this date, a few days before flowering, in June, seeks to reduce the number of indeterminate panicles and reduce the vegetative flow that may occur soon after blooming. This drain can harm not only flowering but also fruiting in the next stage because, in the next few days, there is a significant demand for carbohydrates (WOLSTENHOLME, 1990). Furthermore, applying paclobutrazol in June via soil can avoid the emission of another vegetative flow. PBZ in June must be carefully used because the accentuated reduction of this second flow can leave the fruits in formation without protection and increase damage with sunburn and with few leaves to fill the fruits in the future.

Vegetative Growth

A root regression model represents the first shoot length analyses; the minor branch length was achieved in the bigger doses (Model 7). As we see in all experiments, avocado is very responsive to PBZ, reducing vegetative growth in doses of more than 1,0g.m^{-1}.

Model 7 – Regression model for shoot length of avocado plants treated with different doses of paclobutrazol applied in July 2022.



Flowering

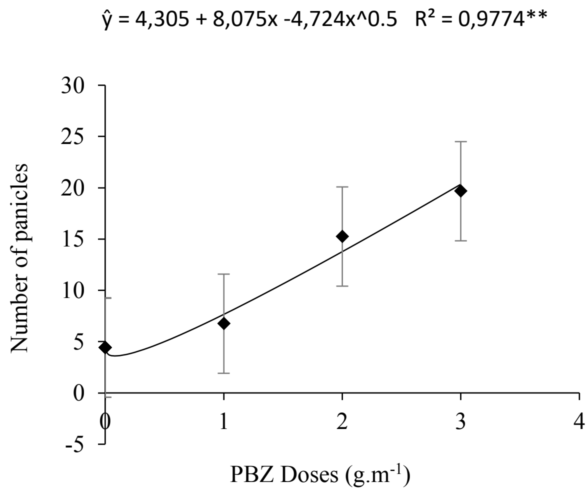
Indeterminate panicles

The number of indeterminate panicles does not behave as seen in other experiments; it was impossible to design a regression model. Plants in the same treatments do not follow a pattern for these traits.

Determinate panicles

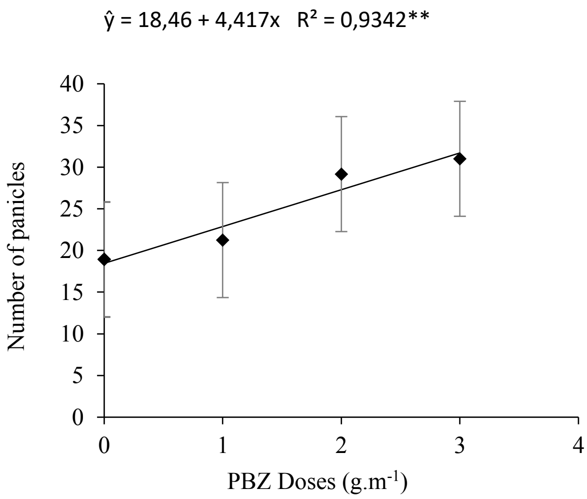
It was possible to use a root regression model to represent the interaction between the doses and the number of determinate panicles (Model 8), increasing with the doses, as we see in most of the tests in this article. A linear progression fits better for total panicles (Model 9).

Model 8 – Regression model for number of panicles per branch of avocado plants treated with different doses of paclobutrazol applied in May 2022.



<u>Total panicles</u>

Model 9 – Regression model for number of panicles per branch of avocado plants treated with different doses of paclobutrazol applied in May 2022.



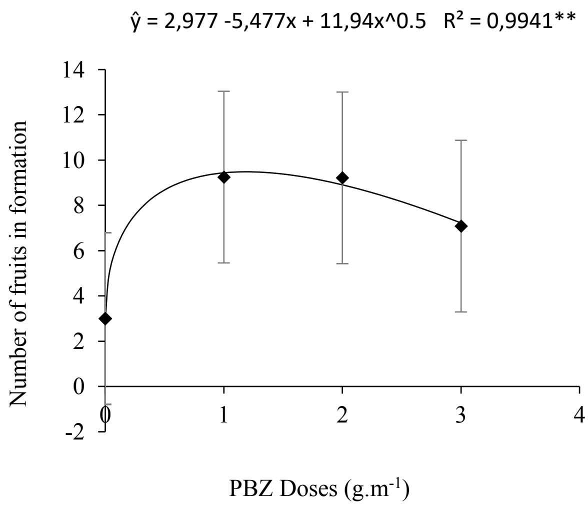
Second growth

Like in indeterminate panicles, the effect of PBZ in the second analysis of shoot length did not have a significative regression model; the dense planting probably caused this lack of pattern between repetitions. Avocado is responsible for solar radiation, primarily to bloom. The plants in this experiment were shaded by neighboring plants, which could cause this considerable variation between them; besides that, Mouco 2005 analyzing the effect of PBZ in mangos, concludes that the application of the product has more impact when applied in warmer periods. Therefore, continuity applications in the next cycle are necessary to verify the results and accentuate the effect of the product on the plants.

Fruiting

Despite the low effect of the product in later evaluations for applications in June, the number of fruits follows a root model of regression for the number of fruits per branch (Model 10), illustrating the trend towards an increase in the number of fruits with increasing dose. The 2g dose being the most efficient was probably caused by the effect of the product increasing total panicles. Doses between 1,0 and 2,0 g.m-1 were more efficient, probably because a high dose of paclobutrazol can cause uncontrolled growth of panicles with low fruit set.

Model 10 – Regression model for number of fruits per branch of avocados plants treated with different doses of paclobutrazol applied in May 2022.



A continuous application during the following years can help to understand this product's effect on avocado growth even more.

CONCLUSION

The PBZ could reduce the avocado branch length cultivated in Minas Gerais in all application months, mainly for application in soil, using 3,0 g.m^{-1}. None of the treatments was able to anticipate flowering.

The use of floral induction protocol and 3,0 g.m^{-1} in May seems to benefit the results in the plants; the PBZ also improves the number of total panicles and determinate panicles, possibly leading to more fruits.

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4. GENERAL CONCLUSION

All the data in this work is from only one year of studies. The response of the continuous use of paclobutrazol is necessary. With the development and continuation of the studies carried out in this thesis, we can increase the state of Minas Gerais avocado production. We will be able to produce with more quality and quantity, developing technologies for culture consciously and sustainably.

The potential impact will affect not only the region, with increased production potential and job and income generation but also scientific production, which is necessary for the avocado producers. Developing innovative methods for avocado production with technologies not yet used in other producing countries will be possible.

The specific crop management for the region leads to the regionalism innovation of the crop to provide a product with characteristics inherent to the region that will allow the characterization of geographical indication.

5. APPENDIX

ANOVA Height 2021

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Height (m)	4,0	0,1659722	0,0414931	2,88 ^{Ns}	0,070	Média geral	1,78
Blocos	3,0	0,0335394	0,0111798	0,78 ^{Ns}	0,530	Height (m)	2,88^{Ns}
Resíduo	12,0	0,1730633	0,0144219			C.V.(%)	6,74
Total	19,0	0,372575					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Height 2022

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Height (m)	4,0	0,1358889	0,0339722	1,26 ^{Ns}	0,337	Média geral	2,61
Blocos	3,0	0,1027778	0,0342593	1,27 ^{Ns}	0,328	Height (m)	1,26^{Ns}
Resíduo	12,0	0,3227778	0,0268981			C.V.(%)	6,28
Total	19,0	0,5614444					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Pruning 2021

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Pruning	4,0	149,45203	37,363008	5,96 **	0,007	Avg	7,64
Blocks	3,0	14,37462	4,79154	0,76 ^{Ns}	0,535	Pruning	5,96**
Residual	12,0	75,20993	6,2674942			C.V.(%)	32,77
Total	19,0	239,03658					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Pruning 2022

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Pruning	4,0	7509,857	1877,4643	10,02 **	< 0.001	Avg	30,67
Blocks	3,0	208,01	69,336667	0,37 ^{Ns}	0,776	Pruning	10,02**
Residual	12,0	2247,815	187,31792			C.V.(%)	44,62
Total	19,0	9965,682					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Canopy Diameter 2021

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Diameter	4,0	0,5959611	0,1489903	1,50 ^{Ns}	0,264	Avg	2,28
Blocks	3,0	0,320176	0,1067253	1,07 ^{Ns}	0,398	Diameter	1,5^{Ns}
Residual	12,0	1,1951789	0,0995982			C.V.(%)	13,83
Total	19,0	2,111316					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Canopy Diameter 2022

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Diameter	4,0	0,3405556	0,0851389	1,18 ^{Ns}	0,370	Avg	3,03
Blocks	3,0	0,2179444	0,0726481	1,00 ^{Ns}	0,425	Diameter	1,18^{Ns}
Residual	12,0	0,869	0,0724167			C.V.(%)	8,9
Total	19,0	1,4275					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Trunk Diameter 2021

F.V.		GL	SQ	QM	F	*p-valor*	FV		
Diameter	**t (m)**	4,0	0,0146578	0,0036644	1,50 ^{Ns}	0,264	Avg	geral	0,30
Blocks	**ocos**	3,0	0,0077444	0,0025815	1,05 ^{Ns}	0,404	Diameter	t (m)	1,5^{Ns}
Residual	**íduo**	12,0	0,0293778	0,0024481				C.V.(%)	16,55
Total	**Total**	19,0	0,05178						

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Trunk Diameter 2022

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Diameter	4,0	0,0044611	0,0011153	0,55 ^{Ns}	0,704	Avg	0,53
Blocks	3,0	0,0051483	0,0017161	0,84 ^{Ns}	0,496	Diameter	0,55^{Ns}
Residual	12,0	0,02441	0,0020342			C.V.(%)	8,52
Total	19,0	0,0340194					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

Summary of ANOVA Longitudinal Diameter, Latitudinal Diameter, Oil %, Fruit Weight 2021

F.V.	GL	Mean Squares			
		DLo	DLa	Oil(%)	Weight(kg)
Rootstock	4	0,804552^{Ns}	0,006974^{Ns}	18,0658**	22,16412^{Ns}
Blocks	3	0,800173^{Ns}	0,24563^{Ns}	1,02493^{Ns}	11,51179^{Ns}
Residual	11	0,860456	0,17230	1,67406	18,44028
CV(%)	-	10,30	6,56	9,77	80,75

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

Summary of ANOVA Longitudinal Diameter, Latitudinal Diameter, Oil %, Fruit Weight 2022

F.V.	GL	Mean Squares			
		DLo	DLa	Oil(%)	Weight(kg)
Rootstock	4	0,94458Ns	0,03824Ns	19,4585**	360,5Ns
Blocks	3	0,48565Ns	0,06851Ns	1,89074Ns	178,2527Ns
Residual	11	0,610261	0,0686	1,18067	376,3993
CV(%)	-	7,56	3,68	8,01	45,17

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

Summary of ANOVA chlorophyll *a*, chlorophyll *b*, total chlorophyll, carotenoids of avocados in different seasons 2021.

F.V.	**GL**	**Mean Squares**			
		Clo(*a*)	Clo (*b*)	Clo T	Carot
Rootstock	4	0,023467 Ns	0,005366 Ns	0,048457 Ns	0,00006 Ns
Season	2	4,6165 **	0,5694 **	4,047023 **	0,013 **
RootSxSeason	8	0,067512 **	0,0106 *	0,127915 **	0,0000742 *
Treatment	14	0,704783 **	0,088933 **	0,665084 **	0,00192 **
Blocks	3	0,018114 Ns	0,0004385 Ns	0,037557 Ns	0,000114 *
Residual	42	0,017839	0,004196	0,036152	0,0000318
CV(%)	-	17,15	16,35	9,77	11,32

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

Summary of ANOVA photosynthesis, stomatal conductance, Ci, Trmmol and Efficiency of water use of avocado on different seasons 2021.

F.V.	**GL**	**Mean Squares**				
		Photo	Cond	Ci	Trmmol	Ef
Rootstock	4	10,03238564**	0,000097Ns	867,0427*	0,160483Ns	0,244201Ns
Season	2	804,7811525**	0,113763**	8346,646**	109,9791**	6,350192**
RootSxSeason	8	3,153547956~	0,00024Ns	882,8489*	0,15738Ns	0,16483Ns
Treatment	14	119,6371594**	0,016416**	1944,59**	15,84708**	1,07113Ns
Blocks	3	3,21786816Ns	0,003006**	854,0881Ns	2,593756**	0,994346Ns
Residual	42	2,255508859	0,000335	303,1404	0,276357	0,568461
CV(%)	-	10,34	10,62	7,61	12,09	21,06

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Shoot Length of avocado treated with paclobutrazol in December 2021

F.V.	**GL**	**SQ**	**QM**	**F**	***p-valor***	**FV**		
Treatment	4,0	129,91716	32,479291	6,56 **	< 0.001	Avg	ral	13,00
Blocks	8,0	15,733838	1,9667298	0,40 ^{Ns}	0,914	Treatments	tos	6,56**
Residual	32,0	158,4722	4,9522561				C.V.(%)	17,11
Total	44,0	304,1232						

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Flowering of avocado treated with paclobutrazol in December 2021

F.V.	GL	SQ	QM	F	p-valor	FV	
Treatment	4,0	349,2	87,3	2,15 Ns	0,098	Avg	17,09
Blocks	8,0	387,64444	48,455556	1,19 Ns	0,334	Treatments	2,15Ns
Residual	32,0	1300,8	40,65			C.V.(%)	37,31
Total	44,0	2037,6444					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Shoot Length of avocado treated with paclobutrazol in March 2021

F.V.	GL	SQ	QM	F	p-valor	FV	
Treatment	4,0	1828,2877	457,07193	107,90 **	< 0.001	Avg	27,33
Blocks	5,0	34,151431	6,8302862	1,61 Ns	0,202	Treatments	107,9**
Residual	20,0	84,723915	4,2361958			C.V.(%)	7,53
Total	29,0	1947,1631					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Number of determinate panicles of avocado treated with paclobutrazol in March 2021

F.V.	GL	SQ	QM	F	p-valor	FV	
Treatment	4,0	2492,1333	623,03333	39,60 **	< 0.001	Avg	9,63
Blocks	5,0	30,166667	6,0333333	0,38 Ns	0,854	Treatments	39,6**
Residual	20,0	314,66667	15,733333			C.V.(%)	41,18
Total	29,0	2836,9667					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Number of mixed panicles of avocado treated with paclobutrazol in March 2021

F.V.	GL	SQ	QM	F	p-valor	FV	
Treatment	4,0	2186,8667	546,71667	11,82 **	< 0.001	Avg	20,40
Blocks	5,0	63,6	12,72	0,28 Ns	0,921	Treatments	11,82**
Residual	20,0	924,73333	46,236667			C.V.(%)	33,33
Total	29,0	3175,2					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Mixed panicles shoot length of avocado treated with paclobutrazol in March 2021

F.V.	GL	SQ	QM	F	p-valor	FV	
Treatment	4,0	414,10397	103,52599	9,22 **	< 0.001	Avg	18,71
Blocks	5,0	52,577747	10,515549	0,94 Ns	0,478	Treatments	9,22**
Residual	20,0	224,46888	11,223444			C.V.(%)	17,9
Total	29,0	691,1506					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Total Flowers of avocado treated with paclobutrazol in March 2021

F.V.	GL	SQ	QM	F	p-valor	FV	
Treatment	4,0	3479,8	869,95	13,65 **	< 0.001	Avg	30,03
Blocks	5,0	148,56667	29,713333	0,47 ^{Ns}	0,797	Treatments	13,65**
Residual	20,0	1274,6	63,73			C.V.(%)	26,58
Total	29,0	4902,9667					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Shoot Length of avocado treated with paclobutrazol in May 2021

F.V.	GL	SQ	QM	F	p-valor	FV	
Treatment	3,0	972,61742	324,20581	73,73 **	< 0.001	Avg	19,40
Blocks	8,0	81,566174	10,195772	2,32 ^{Ns}	0,053	Treatments	73,73**
Residual	24,0	105,53632	4,3973466			C.V.(%)	10,81
Total	35,0	1159,7199					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Number of determinate panicles of avocado treated with paclobutrazol in May 2021

F.V.	GL	SQ	QM	F	p-valor	FV	
Treatment	3,0	1080,2222	360,07407	37,12 **	< 0.001	Avg	10,00
Blocks	8,0	53	6,625	0,68 ^{Ns}	0,702	Treatments	37,12**
Residual	24,0	232,77778	9,6990741			C.V.(%)	31,14
Total	35,0	1366					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Number of mixed panicles of avocado treated with paclobutrazol in May 2021

F.V.	GL	SQ	QM	F	p-valor	FV	
Treatment	3,0	839,66667	279,88889	14,80 **	< 0.001	Avg	25,94
Blocks	8,0	128,38889	16,048611	0,85 ^{Ns}	0,571	Treatments	14,8**
Residual	24,0	453,83333	18,909722			C.V.(%)	16,76
Total	35,0	1421,8889					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Mixed panicles shoot length of avocado treated with paclobutrazol in May 2021.

F.V.	GL	SQ	QM	F	p-valor	FV	
Treatment	3,0	563,84857	187,94952	46,03 **	< 0.001	Avg	12,70
Blocks	8,0	15,308095	1,9135118	0,47 ^{Ns}	0,866	Treatments	46,03**
Residual	24,0	97,990766	4,0829486			C.V.(%)	15,92
Total	35,0	677,14743					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Total Flowers of avocado treated with paclobutrazol in May 2021

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Treatment	3,0	3651	1217	57,55 **	< 0.001	Avg	35,94
Blocks	8,0	253,38889	31,673611	1,50 ^{Ns}	0,210	Treatments	57,55**
Residual	24,0	507,5	21,145833			C.V.(%)	12,79
Total	35,0	4411,8889					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Shoot Length of avocado treated with paclobutrazol in June 2021

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Treatment	3,0	23,05627	7,6854234	2,69 ^{Ns}	0,062	Média geral	4,86
Blocks	11,0	24,368214	2,2152921	0,78 ^{Ns}	0,661	Comprimento Brotação	2,69 ^{Ns}
Residual	33,0	94,263751	2,8564773			C.V.(%)	34,74
Total	47,0	141,68823					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Number of determinate panicles of avocado treated with paclobutrazol in June 2021

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Treatment	3,0	1841,8958	613,96528	13,12 **	< 0.001	Média geral	11,52
Blocks	11,0	542,22917	49,293561	1,05 ^{Ns}	0,425	Comprimento Brotação	13,12**
Residual	33,0	1543,8542	46,78346			C.V.(%)	59,37
Total	47,0	3927,9792					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Number of mixed panicles of avocado treated with paclobutrazol in June 2021

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Treatment	3,0	82,229167	27,409722	1,06 ^{Ns}	0,377	Média geral	13,56
Blocks	11,0	230,0625	20,914773	0,81 ^{Ns}	0,628	Comprimento Brotação	1,06 ^{Ns}
Residual	33,0	849,52083	25,743056			C.V.(%)	37,41
Total	47,0	1161,8125					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Mixed panicles shoot length of avocado treated with paclobutrazol in June 2021.

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Treatment	5,0	398,37809	79,675618	19,51 **	< 0.001	Média geral	11,23
Blocks	10,0	40,580915	4,0580915	0,99 ^{Ns}	0,461	Comprimento Brotação	19,51**
Residual	50,0	204,15498	4,0830995			C.V.(%)	17,99
Total	65,0	643,11398					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Total Flowers of avocado treated with paclobutrazol in June 2021

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Treatment	3,0	1252,8333	417,61111	4,39 *	0,010	Média geral	25,08
Blocks	11,0	750,66667	68,242424	0,72 ^{Ns}	0,714	Comprimento Brotação	4,39*
Residual	33,0	3140,1667	95,156566			C.V.(%)	38,89
Total	47,0	5143,6667					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Initial fructification of avocado treated with paclobutrazol in March 2021

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Treatment	4,0	2142,3333	535,58333	14,54 **	< 0.001	Mean	24,50
Blocks	5,0	226,3	45,26	1,23 ^{Ns}	0,333	Treatments	14,54**
Residual	20,0	736,86667	36,843333			C.V.(%)	24,77
Total	29,0	3105,5					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Initial fructification of avocado treated with paclobutrazol in May 2021

F.V.	GL	SQ	QM	F	*p-valor*	FV	
Treatment	3,0	1394,4444	464,81481	9,79 **	< 0.001	Mean	22,33
Blocks	8,0	330	41,25	0,87 ^{Ns}	0,555	Treatments	9,79**
Residual	24,0	1139,5556	47,481481			C.V.(%)	30,85
Total	35,0	2864					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.

ANOVA Initial fructification of avocado treated with paclobutrazol in June 2021

F.V.	GL	SQ	QM	F	*p-valor*	FV	*(Box-Cox (y+1), λ= -0,23)*
Treatment	5,0	12,167707	2,4335415	5,29 **	< 0.001	Mean	1,23
Blocks	11,0	5,2933645	0,481215	1,05 ^{Ns}	0,420	Treatments	5,29**
Residual	55,0	25,281191	0,459658			C.V.(%)	55,31
Total	71,0	42,742263					

**- Significant at 1% probability by F test. ns - F not significant at 5% probability.