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New orthotropic stems induction in arabica coffee by pruning and biostimulant application

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ABSTRACT

Pruning are techniques used to renew a coffee tree and promote the growth of a more vigorous plant. Allied to that, the use of biostimulants can help the boost growth and development of the new produced stems. The objective of the present work was to evaluate whether the presence of plagiotropic branches in coffee trees pruned by low pruning and the application of biostimulant would influence the production, growth and vigor of new orthotropic branches in *Coffea arabica*. The experiment consisted of 10 treatments, arranged in a randomized block design with a 2x5 factorial: two pruning methods (low pruning with and without plagiotropic branches) and five doses of Stimulate® (0, 100, 200, 400 and 800 mL). The traits evaluated were vigor of the orthotropic branches produced vigor, orthotropic branches length, number of orthotropic branches orthotropic and orthotropic branches diameter. The use of low pruning with remaining plagiotropic stems combined with the use of biostimulants at a dose of 400 mL induces the production of vigorous orthotropic stems in Arabica coffee trees.

Key words: *Coffea arabica*; coffee pruning; phytohormones; shoots.

1 INTRODUCTION

Brazil is the largest producer and exporter of coffee, accounting for around 34% of world production. The estimate for the 23/24 harvest is 58 million bags (Companhia Nacional de Abastecimento - CONAB, 2024). In view of this, it is important that new cropping strategies and technologies are developed to enable this position of excellence.

One of the strategies for renewing the crop and maintaining high yields is pruning. The stumping pruning method is used to renew the coffee plantation and promote the growth of new orthotropic stems that will give rise to new productive or plagiotropic branches. This pruning method is considered drastic and consists of cutting the coffee plant 30 to 40 centimeters from the ground.

It is known that similar to what happens on a commercial scale with the *Coffea canephora* species, the orthotropic stems of the *Coffea arabica* can be used in the rooting of cuttings to produce clones identical to the mother plant. The development of methodologies for cuttings/minicuttings is of great value for breeding programs, where the propagation of a superior plant would be facilitated. Several studies have been carried out in this line of research (Azevedo et al., 2020; Pereira et al., 2018; Rezende et al., 2017).

In addition to the development of new strategies to improve the development and production of coffee crops, biostimulants deserve to be highlighted (Ferreira et al., 2018). The use of biostimulants has been widely used in recent studies and on various crops, showing significant results (Prado Neto et al., 2007; Canesin et al., 2012; Scalon et al., 2009). Therefore, the development of seedlings, adult crops and pruned plants can be enhanced by its use.

The objective of the present work was to evaluate whether the presence of plagiotropic branches in coffee trees pruned by low stumping method and the application of biostimulant would influence the production, growth and vigor of new orthotropic branches in Coffea arabica. It is important to note that this work could open the way for new clonal garden methodologies for the species and improve the process of multiplying superior plants in breeding programs.

2 MATERIAL AND METHODS

2.1 Experiment site characteristics

This experiment was carried out in a coffee plantation located in the Coffee Crops sector of the Agriculture Department of the Federal University of Lavras, Minas Gerais, Brazil, at the following coordinates 21°13’40’’S e 44°57’38’’W, 967 altitude meters. According to the Koppen classification, the region’s climate is characterized as Cwa, classified as humid subtropical, with dry winters and rainy summers (Sá et al., 2012). The soil in the experimental area is a dystroferric dark red Oxisol with clayey texture (Curi et al., 2019).

Coffee plants of the species *Coffea arabica* cv. Catuaí Vermelho IAC-144 were used in this study. At the time of pruning, the plants were 15 years old, planted at a spacing of 3.5 x 0.5 meters, and had been managed according to the recommended cultural treatments for the region (Guimarães et al., 1999). When the experiment was set up, the soil in the selected plots was sampled (Table 1).

2.2 Design and experimental characteristics

The experiment began with the separation of plants and pruning in July 2020 and was completed and evaluated in January 2021, for a total duration of six months. The experimental plots were laid out in a randomized block design in a 2x5 factorial scheme with 4 replications, totaling 40 experimental units (Table 2).

The useful experimental unit consisted of five plants, which were evaluated at the end of the experiment. The plants were pruned 40 centimeters off the ground. In the treatments that received pruning 2 (low stumping with plagiotropic stems), the standardization was 3 plagiotropic stems per plant. The pruning was carried out using a chainsaw and spare plagiotropic branches were thinned out by hand when necessary.

The biostimulant used was Stimulate® (kinetin + gibberellic acid + 4-indol-3ylbutyric acid, 0.009% + 0.005% + 0.005%). Stimulate® applications were carried out using a hand-held backpack sprayer and the solutions were prepared at the time of spraying. Spraying was carried out in the morning, between 08:00 and 09:00 hours, when temperatures were milder. The applications were carried out the day after pruning. Below is a graph showing the environmental characteristics during the experiment (Figure 1).

2.3 Analyzed variables and statistical analysis

At 180 days after spraying, the experimental plots were evaluated for the following characteristics:

- Vigor of new orthotropic branches: the shoots were given scores from 1 to 5 by three evaluators.
- Orthotropic stems length: all the new stems produced were collected and measured using a graduated ruler, obtaining the average.
- Number of new orthotropic stems produced.
- Orthotropic stems diameter: measured at the base of the orthotropic branches each plant using a digital caliper, obtaining the average.

The data compiled was subjected to the F test and when significant differences were found, the qualitative data was compared using the Tukey test (5% significance level). Regression models were fitted to the quantitative data. Statistical analyses were carried out using the R software (R Core Team, 2023).

Table 1: Soil chemical analysis before experiment implementation. Lavras - MG, 2021.

Depth (m)	pH	P	K	Ca	Mg	Al	(H + Al)	SB	t	T
0 - 0.20	5.4	6.8	122	1.8	0.6	0.3	3.19	2.71	3.01	5.9
	V	m	M.O.	P-Rem	S	Fe	Mn	Cu	Zn	B
0 - 0.20	45.93	5.08	2.23	24.56	30.5	98.6	19.8	5.2	3.5	0.5

Source: The authors (2021).

Note: pH (H_2O); P and K (mg dm^{-3}); Ca^{2+}, Mg^{2+}, Al^{3+}, $H^+ + Al^{3+}$ (cmolc dm^{-3}); SB = exchangeable base sum (cmolc dm^{-3}); (t) = effective cation exchange capacity (cmolc dm^{-3}); (T) = cation exchange capacity at pH 7.0 (cmolc dm^{-3}); V = base saturation index (%); m = aluminum saturation index (%); M. O. (dag kg^{-1}); P-Rem (mg L^{-1}); Zn, Fe, Mn, Cu, B, S (mg dm^{-3}).

Table 2: Layout of the treatments in this experiment. Lavras - MG, 2021.

Treatments	Stumping method / Biostimulant approach*
T1	Stumping 1 / No biostimulant
T2	Stumping 1 / 100 mL (1/2 commercial dose)
T3	Stumping 1 / 200 mL (Commercial dose)
T4	Stumping 1 / 400 mL (2 x commercial dose)
T5	Stumping 1 / 800 mL (4 x commercial dose)
T6	Stumping 2 / No biostimulant
T7	Stumping 2 / 100 mL (1/2 commercial dose)
T8	Stumping 2 / 200 mL (Commercial dose)
T9	Stumping 2 / 400 mL (2 x commercial dose)
T10	Stumping 2 / 800 mL (4 x commercial dose)

Note: Stumping 1: low stumping without plagiotropic branches; Stumping 2: low stumping with plagiotropic branches; *: all the biostimulant doses were diluted following the manufacturer's recommendations. Source: The authors (2024).

3 RESULTS

According to the respective analysis of variance, all four traits showed statistical differences by the F test at the 1% level (Table 3). Vigor of new orthotropic stems was the only significant for the simple effect of doses. As for the orthotropic stems length, number of new stems and stem diameter, there was significance for the interaction between the factors, excluding the simple effects.

For vigor of new orthotropic stems, a quadratic regression model was fitted for the effect of the different doses, regardless of the type of pruning adopted (Figure 2).

Based on the adjusted equation and the graph obtained, there is a tendency for vigor of new orthotropic stems to increase as the dose of the biostimulant increases up to 400 mL. Above this dose, there is a trend for the plants to return to the average of dosage of 200 mL, indicating a hormonal overdose for this situation (800 mL). It's important to note that all the treatments were superior to the unapplied control, suggesting that the biostimulant potentiated shoot development.

For the orthotropic stem length attribute, the effect of pruning methods was split within the doses of 0, 100 and 400 mL (Figure 3). Also, the effect of doses was split with the type of pruning (Figure 4).

When analyzing the growth of the stems produced after pruning and the application of the biostimulant, it can be seen that pruning 2 is more efficient in the initial growth of the new shoots. The highest absolute difference can be saw at the 400 mL dose, where the pruning 2 method was over 3 centimeters larger than the stems produced in stumping 1.

Considering the unfolding of the doses of biostimulant within the low stumping management, a pattern similar to that found in the vigor analysis can be seen, i.e. there was a tendency for the growth of new orthotropic stems to increase as the dose rised up to 400 mL (Figure 4). However, when the 800 mL dose was imposed, it can be inferred that the excess hormone imposed on the plants, considering the stress already pre-established by the drastic pruning, had a negative effect on the development of the new stems.

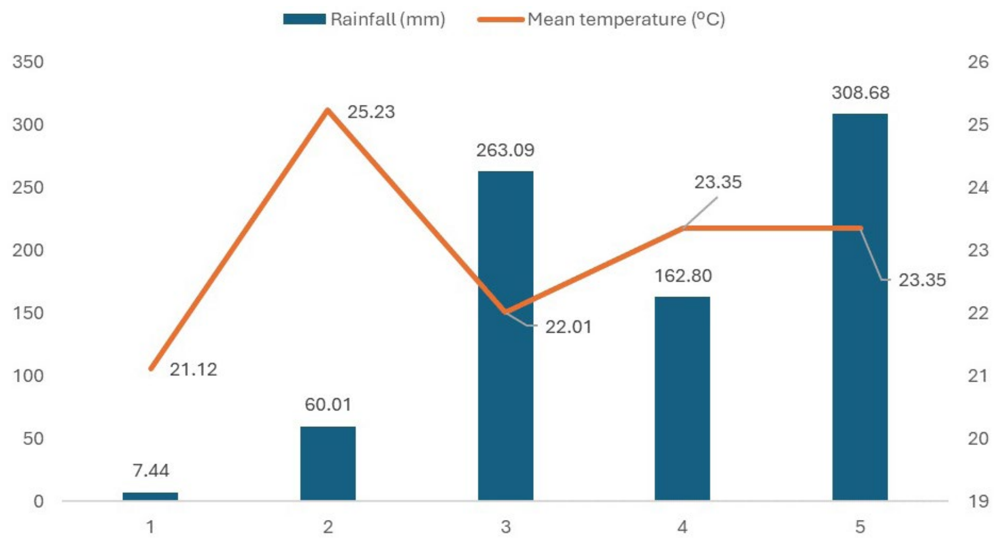

Figure 1: Rainfall (mm) and mean temperature measurements during trial conduction.

Source: The authors (2024).

Note: (1) August; (2) September; (3) October; (4) November; (5) December.

Table 3: Analysis of variance (ANOVA) for all the traits evaluated.

Source of Variation	Mean Squares (MS)			
	Vigor of new orthotropic stems	Orthotropic stems length	Number of new stems	Stem diameter
Pruning	1.445^{ns}	83.851**	222.6**	0.074^{ns}
Doses	6.367**	38.348**	209.818**	0.26055**
Blocks	0.058^{ns}	0.853^{ns}	0.323^{ns}	0.0027^{ns}
Doses x Pruning	0.333^{ns}	23.697**	52.242**	0.197**
Residual	0.589	3.618	2.865	0.020
Means	4.16	39.85	10.29	1.25
CV (%)	18.980	4.78	16.44	11.36

Note: Values followed by ** were statistically significant by F test at 1%. ^{ns}No significance.

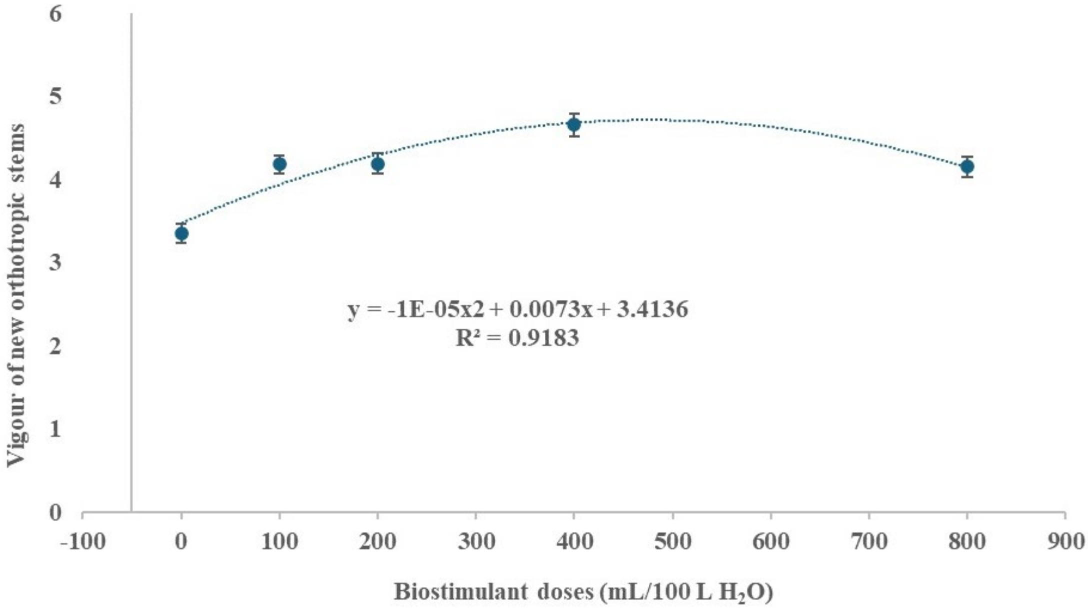

Figure 2: Quadratic regression model fitted for vigor of new orthotropic stems. Source: The authors (2024).

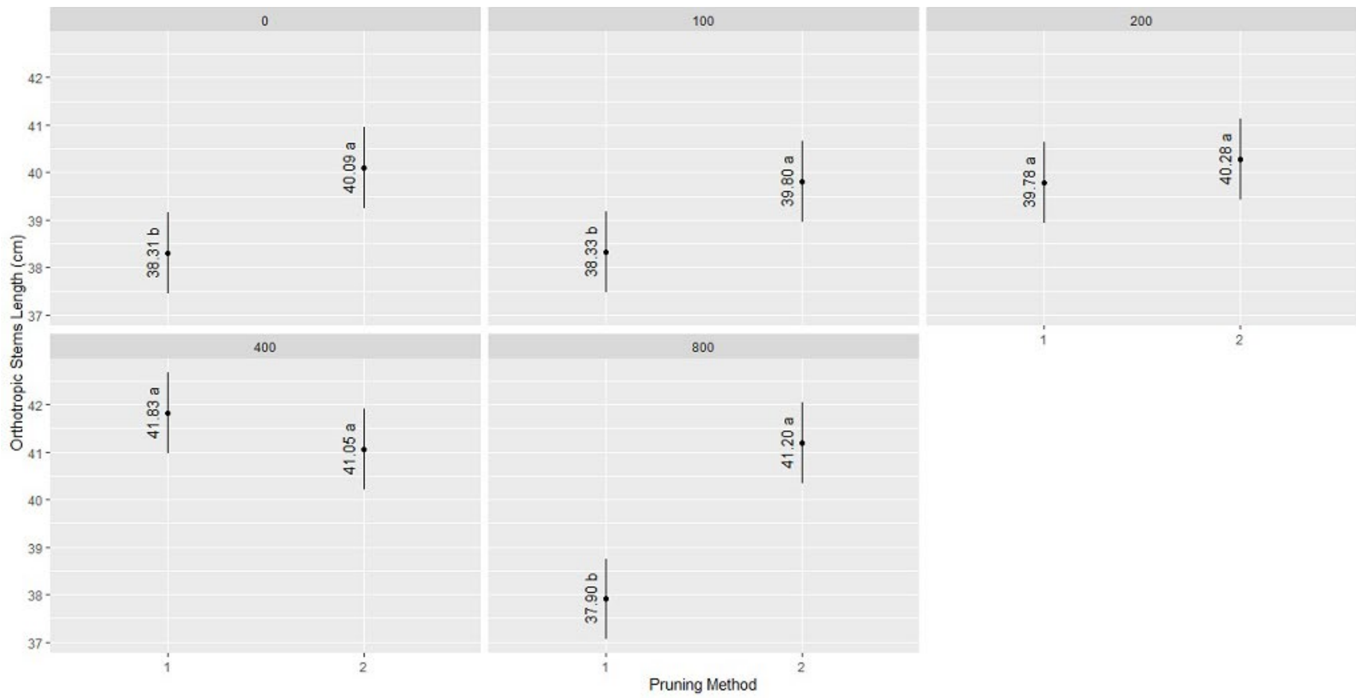

Figure 3: Orthotropic stem length with different doses and pruning methods.

Note: All the treatments followed by the same letter, in each split, did not differ by the Tukey test, $p < 0.05$. (1) Low pruning without plagiotropic branches; (2) Low pruning with remaining plagiotropic stems. Source: The authors (2024).

Analyzing the number of new orthotropic stems (Figure 5), we can see that the pruning 2 method is superior to type of pruning 1, with a tendency to increase as the dosage of the biostimulant rises. At a dose of 100 mL, the plants subjected to type of pruning 2 produced an average of 8.95 new stems, while the type of pruning 1 produced an average of 7.70 new shoots. Considering the dosages of 300 and 400 mL, the plants that had undergone the type of pruning 1 produced an average of 9.85 and 10.15 new shoots, respectively, while the plants that had undergone the type of pruning 2 produced an average of 14.20 and 14.85 new shoots, respectively.

Also, in the number of new stems trait, analyzing the split of doses within the respective pruning methods (Figures 6 and 7), the same trend observed in the previous attributes is maintained, i.e. the response curve to the application of the biostimulant is increasing. Furthermore, it can be seen that in the plants subjected to type of pruning 1 (Figure 6), the increase in dose to 800 mL of Stimulate showed the same pattern as that observed in vigor of new orthotropic stems, where there was a negative effect on vegetative growth.

However, for the plants subjected to 800 mL and under management of low pruning with remaining plagiotropic stems (Figure 7), the results were slightly higher than the dose of 400 mL, indicating that the strategy of said pruning helped the plants to better cope with the overdose of the biostimulant.

When analyzing the data on the diameter of the shoots, there was a split between the pruning and the 400 and 800 mL dose (Figure 8) and, between the doses for each type of pruning (Figures 9 and 10).. Here again, the stumping with plagiotropic branches was superior, with an average diameter of 1.41 mm, 22% more than the low pruning (1.15 mm).

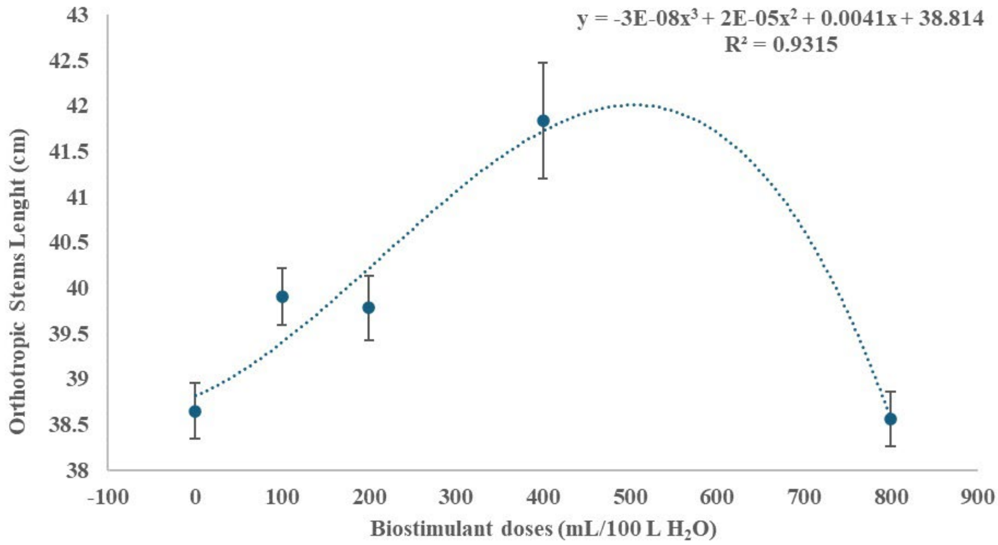

Figure 4: Quadratic regression model fitted for orthotropic stems length.

Source: The authors (2024).

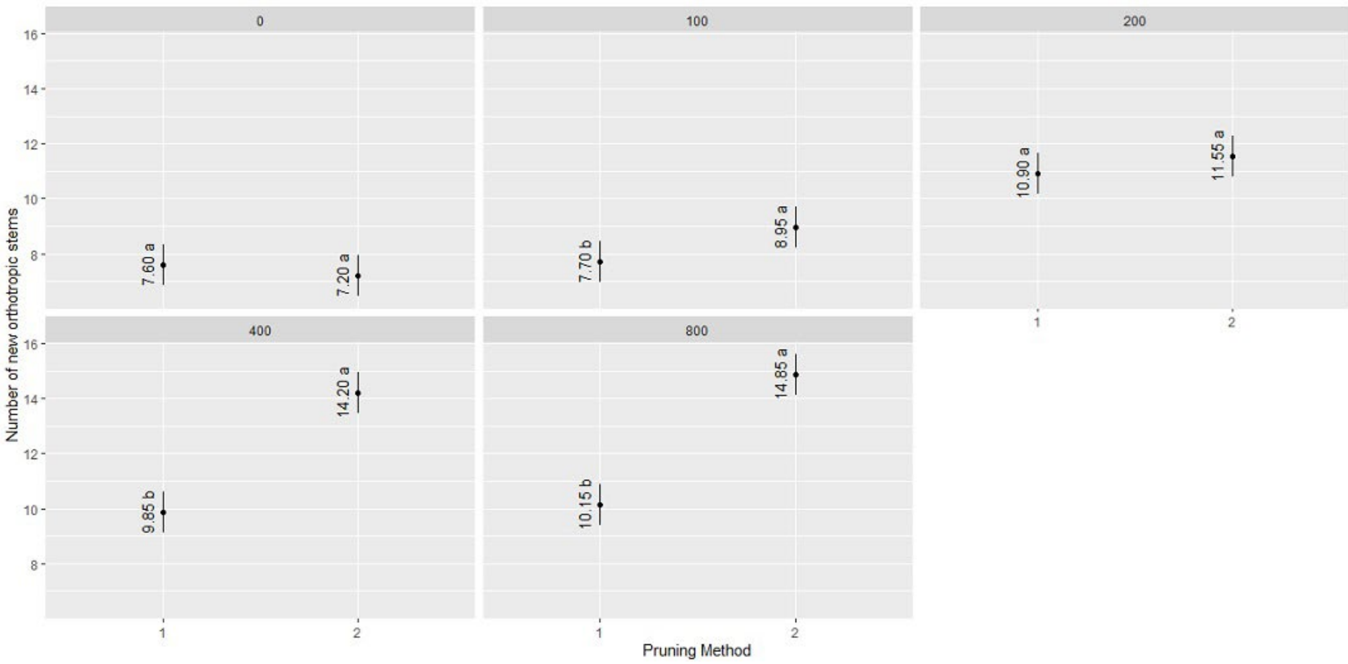

Figure 5: Number of new orthotropic stems within different doses and pruning methods.

Note: All the treatments followed by the same letter, in each split, did not differ by the Tukey test, $p < 0.05$. (1) Low stumping without plagiotropic branches; (2) Low stumping with remaining plagiotropic stems. Source: The authors (2024).

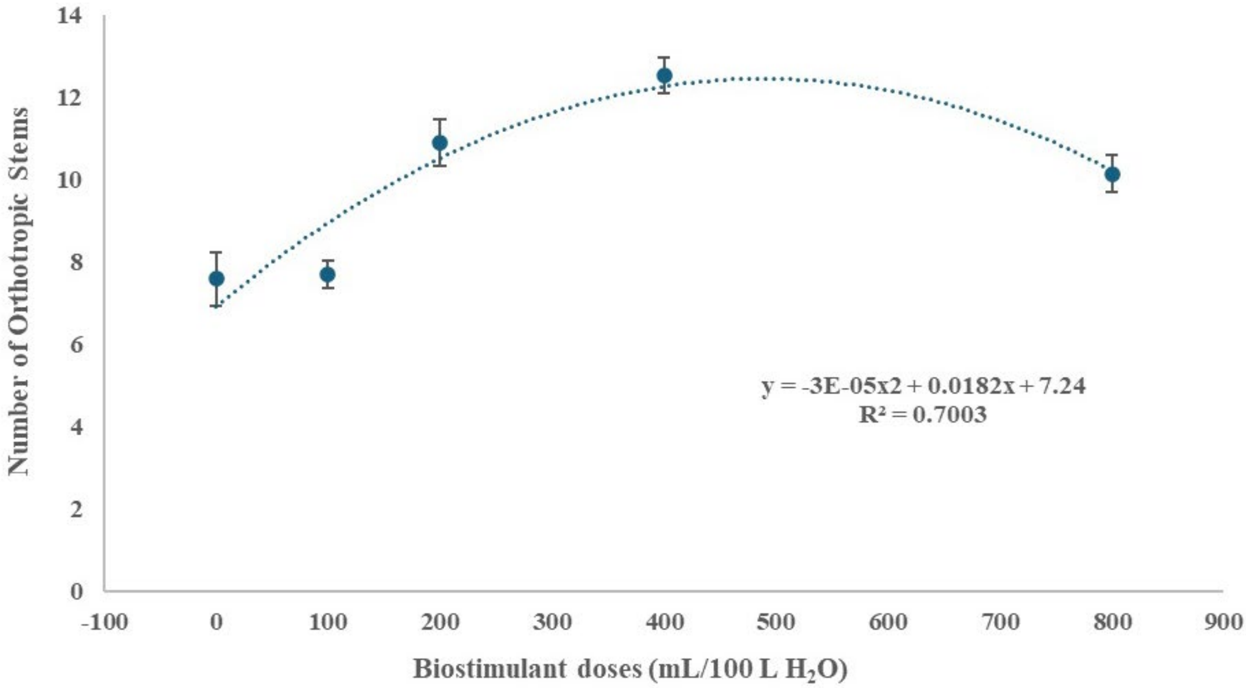

Figure 6: Quadratic regression model fitted for number of new stems within the low stumping pruning method.
Source: The authors (2024).

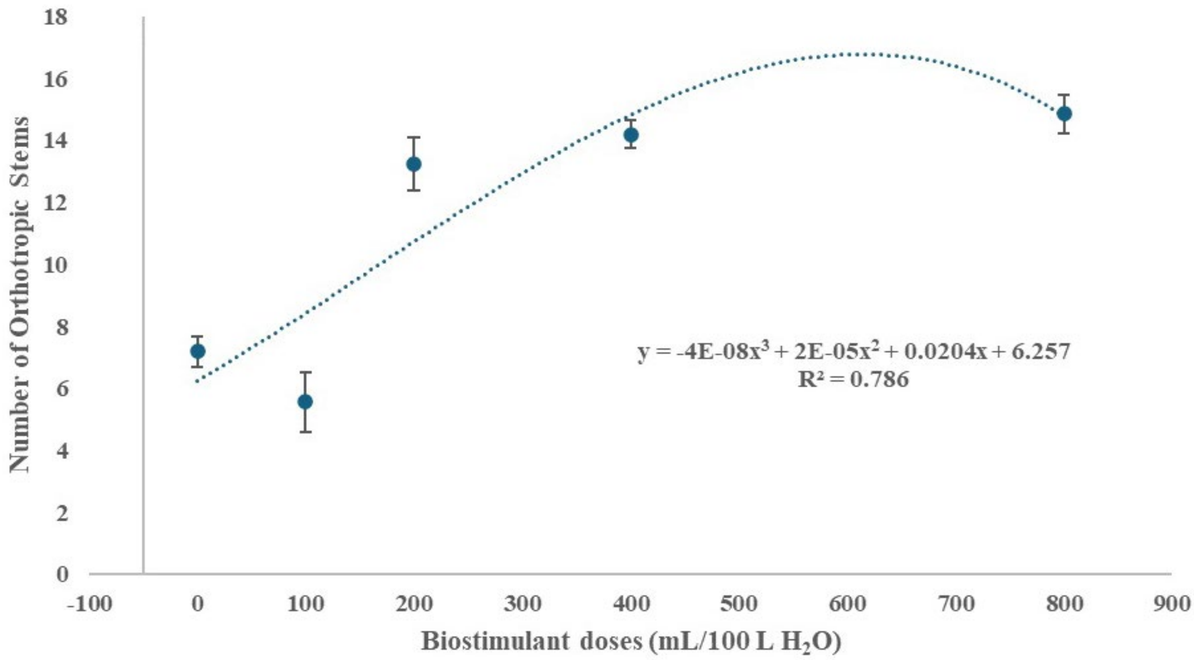

Figure 7: Quadratic regression model fitted for number of new stems within the low stumping with plagiotropic branches pruning method.
Source: The authors (2024).

When unfolding the doses within the low stumping, similarly to the results for vigor of new orthotropic stems, number of orthotropic stems and orthotropic stem length, the response curve shows an increase in stem diameter up to the 400 mL dose (Figure 9).

At the same time, unlike what was observed for the breakdown of doses low stumping pruning with remaining plagiotropic stems on the number of new shoots, the 800 mL dose had a negative effect when compared to the 400 mL dose, i.e. the higher dose led to a greater number of stems with small diameters.

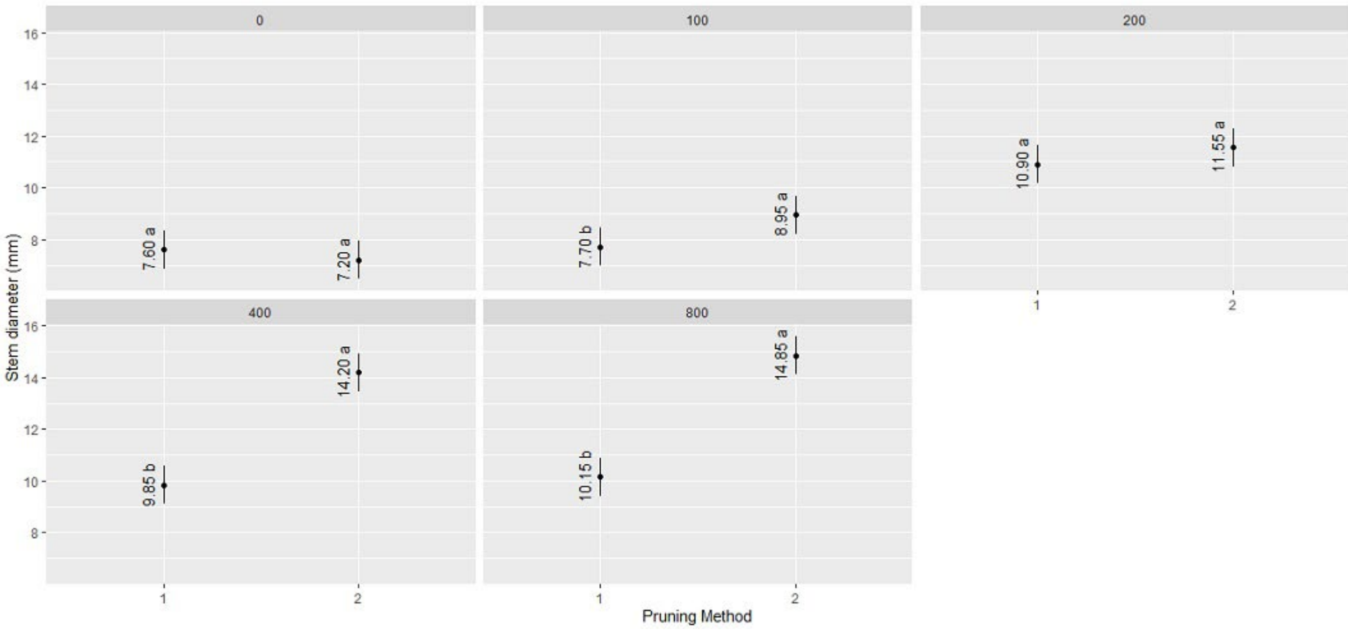

Figure 8: Stem diameter within different doses and pruning methods.

Note: All the treatments followed by the same letter did not differ by the Tukey test, $p < 0.05$. (1) Low stumping without plagiotropic branches; (2) Low stumping with remaining plagiotropic stems. Source: The authors (2024).

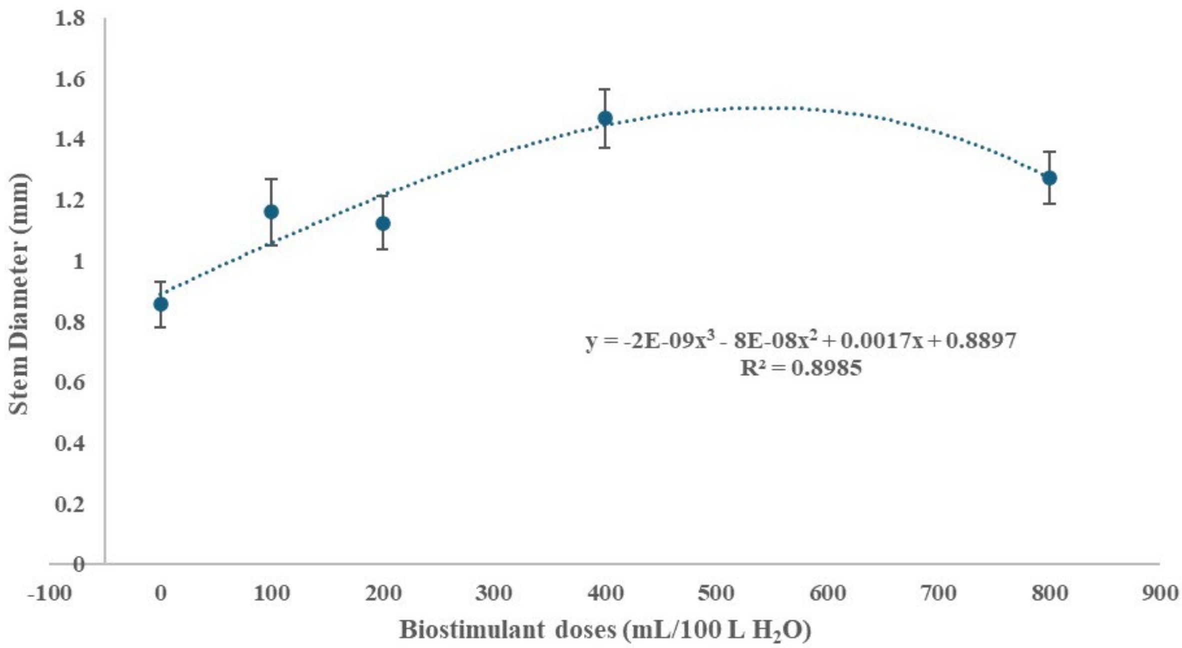

Figure 9: Quadratic regression model fitted for stem diameter within the low stumping pruning method.

Source: The authors (2024).

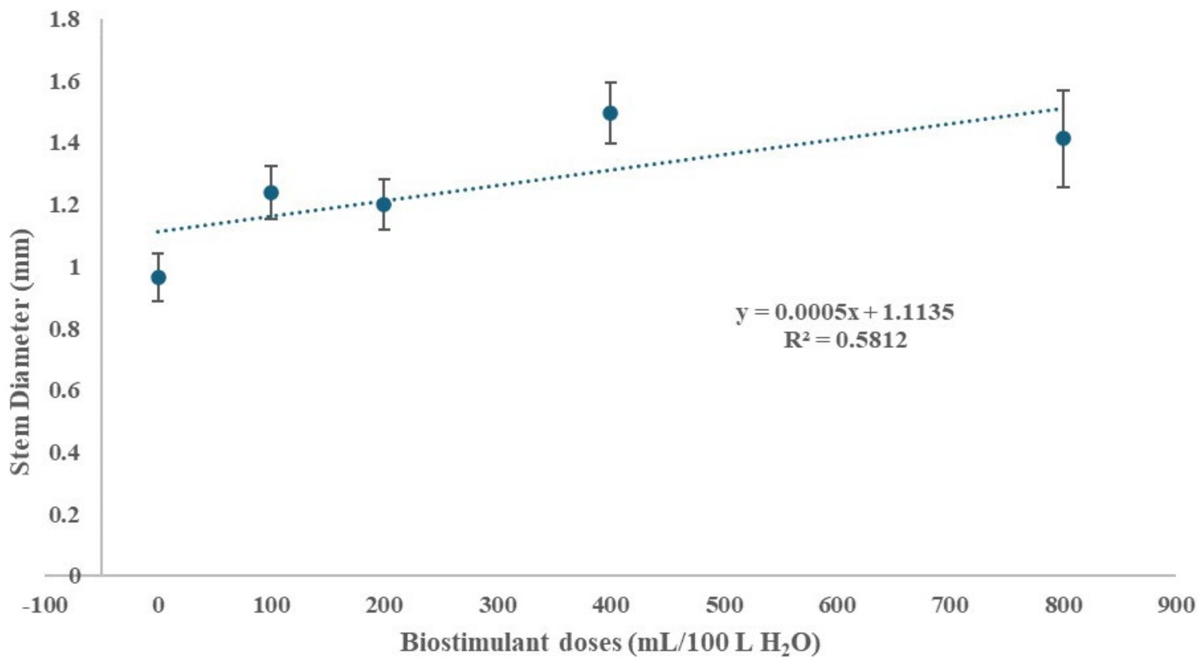

Figure 10: Linear regression model fitted for stem diameter within the low stumping with plagiotropic branches pruning method.
Source: The authors (2024).

4 DISCUSSION

According to the analysis of variance, in addition to the statistical differences, it was found that the experiment had good experimental precision. The coefficients of variation were between 4.78 and 18.98%, similar to studies with coffee trees at field level (Colodetti et al., 2020; Erlacher et al., 2022).

When vigor of new orthotropic stems was analyzed, the effect of applying Stimulate® to the different treatments was clear. The assessment of vigor is linked to the results of growth and development of the shoots, as well as being a strictly visual attribute. Oliveira et al. (2019) showed that the application of biostimulants with a hormonal composition is effective in promoting cell elongation and division, helping both the development of the aerial part and the root system, thus promoting greater vigor of new orthotropic stems.

Furthermore, it is clear from the different characteristics assessed that low stumping with plangiotropic branches (low stumping pruning with remaining plagiotropic stems) was effective in restarting the development of the new shoots that emerged. This may be due to the fact that after this pruning technique, the coffee tree still has some foliage, which, through the interception of photosynthetically active radiation, is responsible for producing photoassimilates to resume growth (Constable; Bange, 2015). On the other hand, plants subjected to low stumping (low stumping pruning without remaining plagiotropic stems) depends exclusively on the sugar reserves present in the plant at the start of the experiment.

When analyzing the orthotropic stem length, these facts were also found in the interaction between doses of the biostimulant and pruning, where regardless of the different doses used, Low stumping pruning with remaining plagiotropic stems was superior. These results corroborate those found in the work by Moreira and Ferraz-Almeida (2021), where the same biostimulant was applied to Arabica coffee seedlings and promoted an increase in the growth of the aerial part. This is due to the fact that the product applied contains auxin in its formulation, which has been proven to help boost growth and the accumulation of plant biomass (Huan et al., 2021; Yao et al., 2019). It is important to remember that one of the functions of auxin is to induce cell division and elongation (Zou et al., 2018).

However, the phytotoxic effect of the product can be observed at high doses after drastic pruning. The effect of high concentrations of auxin applied to plants can inhibit plant growth (Grossmann, 2003; Ye et al., 2019). Also, it is important to point out that biostimulants are efficient when applied in low concentrations, favoring the good performance of various plant processes (Casillas et al., 1986).

In addition, stumping pruning method in itself stimulates the development of new orthotropic stems, since cleaning the plant provides greater aeration and light to the remaining orthotropic branch (Sartori et al., 2007). However, in view of these results, it can be inferred that different pruning managements combined with the use of biostimulants can enhance plant recovery and the production of propagules for a possible genetic improvement program where cuttings would be responsible for the rapid reproduction of individuals genetically identical to the mother plant. (Rezende et al., 2017).

With the accentuated growth resulting from the application of biostimulants, one would think that the stiolation of the larger stems would produce branches with a reduced diameter, which would make it impossible for them to develop in the field after planting. It is important to note that the stem diameter of a coffee seedling is directly related to the success of planting, where seedlings with larger stem diameters are more likely to survive (Tatagiba; Pezzopane; Reis, 2010). However, what was observed was exactly the opposite where, in addition to increasing the number of stems and their length, there was an increase in their diameters also.

5 CONCLUSIONS

The use of low pruning with remaining plagiotropic stems combined with the use of biostimulants at a dose of 400 mL induces the production of vigorous orthotropic stems in Arabica coffee trees.

6 AUTHORS' CONTRIBUTIONS

Conceptual Idea: Honda Filho, C.P.; Coelho, L.S.; Methodology design: Honda Filho, C.P.; Coelho, L.S.; Data collection: Honda Filho, C.P.; Andrade, O.V.S.; Data analysis and interpretation: Honda Filho, C.P.; Godinho, E.Z.; and Writing and editing: Honda Filho, C.P.; Godinho, E.Z.

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