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Yield after intensive pruning of fertigated coffee plants subjected to different macronutrient rates

Produtividade após poda drástica do cafeeiro fertirrigado submetido à diferentes doses de macronutrientes

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Highlights

Fertigation approach associated with intensive pruning of Arabica coffee trees.
Higher yield of post-pruned Arabica coffee fertigated at 100% standard fertilization.
Balanced N, P, and K nutrition optimizes gas exchange through coffee tree leaves.

Abstract

Coffee cultivation holds significant importance both nationally and internationally, with Brazil standing as the leading producer and exporter of this commodity worldwide. A crucial factor for high yield is the appropriate nutrient supply, particularly following intensive pruning. This study aimed to establish fertilization guidelines for fertigated coffee trees post-*recepa* pruning (i.e., stumping or cutting off all plagiotropic branches at 20-30 cm from the orthotropic branch) focusing on reproductive variables and investigating the anatomical and physiological changes in plants fertilized with varying N-P-L levels. The research was conducted in Lavras, MG, Brazil, at the Coffee Production Sector of the Department of Agriculture, Federal University of Lavras (UFLA). Initiated in March 2010, the cultivation involved different fertilization intensities through fertigation, using Topázio MG-1190 cultivar seedlings. The experiment featured five fertilization levels (10, 70, 100%, 130, and 160%) relative to the standard recommendation for rainfed coffee farming. In 2015, the plants underwent "low *recepa*" pruning (no shoots left) and were subsequently assessed for morphology, physiology, and anatomy (2019/2020). A randomized block design was employed, arranged in a factorial scheme with split-plots over time, including three replications. This was structured as a 5×2 factorial (five fertilizer levels and two harvests). The findings indicate that to attain higher yields post-*recepa* pruning, a minimum of 100% of the standard production fertilization is necessary, achieving yields up to 93.05 bags/ha. This requires at least 54.0 g/plant of N

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(450 kg/ha N), 4.0 g/plant of P_2O_5 (33.3 kg/ha P_2O_5), and 20.0 g/plant of K_2O (166.7 kg/ha K_2O). Plants with balanced nutrition, that is, those which receive the recommended rate, exhibit a larger ratio between polar and equatorial diameters of stomata, potentially enhancing gas exchange in coffee leaves.

Key words: *Coffea arabica* L. Macronutrients. Mineral nutrition.

Resumo

O cultivo do cafeeiro tem grande importância no cenário nacional e internacional, sendo o Brasil o maior produtor e exportador mundial dessa commodity. Um dos fatores primordiais para o alcance de altas produtividades é o fornecimento adequado de nutrientes, principalmente após uma poda drástica. Objetivou-se estabelecer recomendação de adubação para o cafeeiro fertirrigado, após poda do tipo *recepa*, por meio de variáveis reprodutivas, além de avaliar as alterações na anatomia e fisiologia das plantas adubadas em diferentes níveis de N, P e K. O experimento foi realizado em Lavras - MG, no Setor de Cafeicultura do Departamento de Agricultura da Universidade Federal de Lavras (UFLA). A lavoura foi implantada em março de 2010 e conduzida com diferentes níveis de adubação (fertirrigação). As mudas utilizadas foram da cultivar Topázio MG-1190. O experimento contou com 5 níveis de adubação (10%, 70%, 100%, 130% e 160%) da adubação padrão recomendada para cafeicultura de sequeiro. Em 2015, as plantas foram submetidas à poda do tipo "*recepa* baixa, sem pulmão", e avaliadas quanto à morfologia, fisiologia e anatomia (2019/2020). O delineamento utilizado foi em blocos ao acaso em esquema fatorial com parcelas subdivididas no tempo, com três repetições, sendo um fatorial 5x2 (cinco níveis de adubação e duas colheitas). De acordo com os resultados obtidos é permitdo conclir que maiores produtividades após *recepa*, são alcançadas com pelo menos 100% da adubação padrão de produção, com produtividade de até 93,05 sacas/ha, são necessários pelo menos 54,0 g/planta de N (450 kg/ha de N); 4,0 g/planta de P_2O_5 (33,3 kg/ha de P_2O_5); e 20,0 g/Planta de K_2O (166,7 kg/ha de K_2O) e plantas com a nutrição equilibrada, ou seja, com a dose recomendada apresentam maior relação entre o diâmetro polar e equatorial dos estômatos, fato esse que pode otimizar as trocas gasosas das folhas do cafeeiro.

Palavras-chave: *Coffea arabica* L. Macronutrientes. Nutrição mineral.

Introduction

Coffee cultivation is a cornerstone of Brazilian agribusiness, with the nation being a global leader as the largest producer and exporter of coffee (Companhia Nacional de Abastecimento [CONAB], 2022). In 2021, Brazil produced 50.9 million bags of processed coffee, exporting about 34.6 million of those (CONAB, 2022). Focusing on Arabica coffee (*Coffea arabica*), which constitutes over 65% of Brazil's coffee output, the 2022 production reached 32.7 million bags of processed grains, with an average yield of 22.5 bags of 60 kg per hectare (CONAB, 2022). To sustain this prominent global position, enhancing management practices for better yields and profitability is crucial. An integral aspect of this is the efficient use of mineral nutrition, which significantly influences the productivity and cost of coffee production. Up to 30% of coffee production costs can be attributed to agricultural correctives and fertilizers (Villela et al., 2015), highlighting the need for advanced understanding and recommendations for coffee plant nutrition (Villela et al., 2015).

Irrigation also plays a vital role in augmenting coffee farm productivity by mitigating production losses during prolonged dry spells and increasing grain production (Turco et al., 2017). In Brazil, irrigated coffee plantations currently cover 25% of the total cultivated area (Agência Nacional de Águas e Saneamento Básico [ANA], 2021). States like Goiás, Espírito Santo, and Rondônia, where over 60% of coffee areas are irrigated, find irrigation indispensable (ANA, 2021). Irrigated coffee crops usually exhibit faster growth, often necessitating pruning to maintain optimal plant architecture and minimize self-shading between rows and loss of plagiotropic branches in the lower portion of the canopy, which could otherwise impact productivity (Assis et al., 2015). In irrigated systems, it is essential to tailor fertilization to the unique growth and productivity patterns, preventing nutrient deficiencies or excesses (Sobreira et al., 2011). Moreover, regardless of the cultivation system, more intensive pruning is typically conducted every five to six years to rejuvenate the crop. Following such pruning, production ceases in the first year and normalizes within two to three years (Aristizábal et al., 2016; Dufour et al., 2019), with proper fertilization being key to encouraging branch growth and restoring productive vigor.

Fertigation, a combined approach of irrigation and fertilization, can reduce labor costs, soil compaction from machinery, and enhance nutrient use efficiency through split applications and uniform distribution (Pinto et al., 2013). Research indicates that fertigation can significantly increase coffee yields with varying rates of nitrogen (N), phosphorus (P), and potassium (K) in the first and second years post-planting (Pinto et al., 2013; Villela et al., 2015; Langoni et al., 2019). Considering the impact of irrigation on coffee tree growth, Resende (2019) studied the growth and yield of coffee trees fertigated with different N-P-K rates before and after the *recepa* pruning (stumping or cutting off all plagiotropic branches at 20-30 cm from the orthotropic branch). This study revealed a linear increase in growth and yield correlating with the rise in fertilization rates, in the period from crop establishment to the first intensive pruning, based on standard recommendations for rainfed coffee farming (Ribeiro et al., 1999). Although Resende (2019) made significant contributions to the fertilization strategies for irrigated coffee farming, it is important to note that the assessment of yield in the study covered only a single year following intensive pruning.

In light of the foregoing, this study aims to establish fertilization guidelines for fertigated coffee trees post-*recepa* pruning, focusing on reproductive variables and the anatomical and physiological changes in plants fertilized with different N-P-K levels.

Material and Methods

This study was conducted in Lavras, Brazil (21°13'S; 44°58' W; 970 m), at the Department of Agriculture, Federal University of Lavras (UFLA). According to Köppen's climate classification, Lavras experiences a Cwa climate, characterized as 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).

The coffee plants used in the experiment, Topázio MG-1190 cultivar, were planted in March 2010, adopting a spacing of 60 cm within rows and 2 m between rows. Different fertilization levels were maintained. In August 2015, "low recepa" pruning was performed at 30 cm above ground. Soil samples for fertilization calculations were collected each October from the 100% plots at a depth of 0-20 cm, using the rate proposed by Ribeiro et al. (1999) as the basis for calculations. Table 1 shows the soil analysis results.

Table 1
Chemical characterization of the soil in the experimental area

Trait	0-20 cm	Trait	0-20 cm
pH (H_2O)	5.5	CEC_7 ($cmol_c.dm^{-3}$)	7.59
P-rem (mg L^{-1})	21.7	BS (%)	44.66
P ($mg.dm^{-3}$)	4.2	AL_S (%)	0.0
K ($mg.dm^{-3}$)	110.2	OM ($dag.kg^{-1}$)	3.0
Ca ($cmol_c.dm^{-3}$)	2.4	Zn ($mg.dm^{-3}$)	6.4
Mg ($cmol_c.dm^{-3}$)	0.7	Fe ($mg.dm^{-3}$)	37.1
Al ($cmol_c.dm^{-3}$)	0.0	Mn ($mg.dm^{-3}$)	11.5
H + Al ($cmol_c.dm^{-3}$)	4.2	Cu ($mg.dm^{-3}$)	1.0
SB ($cmol_c.dm^{-3}$)	3.39	B ($mg.dm^{-3}$)	0.08
CEC_E ($cmol_c.dm^{-3}$)	3.39	S ($mg.dm^{-3}$)	10.1

pH = potential of hydrogen; P-rem = remaining phosphorus; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; Al = aluminum; H+Al = potential acidity; SB = sum of bases; CEC_E = effective cation-exchange capacity; CEC_7 = cation-exchange capacity at pH 7.0; BS% = percentage of base saturation; AlS% = percentage of aluminum saturation; OM = organic matter; Zn = zinc; Fe = iron; Mn = manganese; Cu = copper; B = boron; and S = sulfur.

The experiment was laid out in a randomized block design, consisting of five fertilization levels and four replications, making up 20 plots. Each plot comprised 24 plants (three rows of eight plants), with the middle six plants being the effective plot. This totaled 480 plants over an area of 576 m². The treatments corresponded to 10, 70, 100, 130, and 160% of the standard fertilization recommended by Ribeiro et al. (1999) for rainfed coffee, based on soil analysis (Table 2).

Table 2
Amounts of N, P_2O_5, and K_2O applied in the 2017/2018, 2018/2019, and 2019/2020 crop years. UFLA – MG, 2021

Treatment	N rate (g/plant)	P_2O_5 rate (g/plant)	K_2O rate (g/plant)
10%	5.4	0.4	2.0
70%	37.8	2.8	14.0
100%	54.0	4.0	20.0
130%	70.2	5.2	26.0
160%	86.4	6.4	32.0

Fertilization with nitrogen and potassium was administered via fertigation in 12 equal applications, as suggested by Sobreira et al. (2011), while phosphate fertilizer was split 50% in planting furrows and 50% through fertigation, according to the standard recommendation for rainfed coffee. Urea (45% N), purified MAP (60% P_2O_5 + 11% N), and potassium nitrate (12% N + 43% K_2O) were used as sources of N, P, and K, respectively, in both the 2018/2019 and 2019/2020 crop years. The micronutrients were applied as per the needs of the coffee plantation, exclusively in sprays, as recommended by Ribeiro et al. (1999), without rate variations.

Regarding the fertigation system, drippers were spaced 30 cm apart in the row, creating a wet strip along the plant rows, operating at a nominal flow rate of 3.8 $L.h^{-1}$. Irrigation control utilized daily climatological data from the meteorological station of the National Institute of Meteorology (INMET), located near the experimental area at UFLA. Figure 1 illustrates the daily monthly means of these data. A water balance was calculated using the meteorological data to determine water demand and availability.

Yield evaluation involved separate harvesting of berries from each plot in 2019 and 2020. At harvest, the ripeness stage of the berries was identified, with 10% green and 90% at cherry or overripe stages for most plots. Harvesting was confined to the six central plants in each plot. Post-harvest, measurements were taken in liters (L), and 2-L samples were collected from each plot for patio drying and calculating other evaluated characteristics. These samples were sun-dried on 50 × 50 cm square sieves until reaching an average moisture content of 11%. The samples were then processed, re-weighed, and measured in volume (L), yielding the weight and volume of the processed sample. Using the obtained data, yield was calculated in terms of 60 kg bags per hectare (bags/ha).

The collected data were first tested for normality using the Shapiro-Wilk test, followed by analysis of variance. The significance of variation sources was examined using the F test, at a 5% probability level. When significant, quantitative data underwent regression analysis, while qualitative data were evaluated using the Scott-Knott mean test to elucidate the results. These statistical procedures were performed using SISVAR software (Ferreira, 2019).

Results and Discussion

In analyzing the agronomic variables of productivity and yield, a notable effect was observed due to the level of fertilization, the year, and the interaction between these two factors. This indicates that the productivity of irrigated coffee trees was influenced by the fertilizer rate, the harvest year, and their combined interaction (Table 3). A linear increase in yield was noted with the rise in N-P-K percentages above the standard recommended for rainfed coffee farming. Additionally, both the yield and its growth rate, corresponding to the increase in N-P-K percentages supplied to the plants, were more pronounced in 2019 (Figure 1). The significant disparity in yields across the three harvests highlights the impact of biennial bearing.

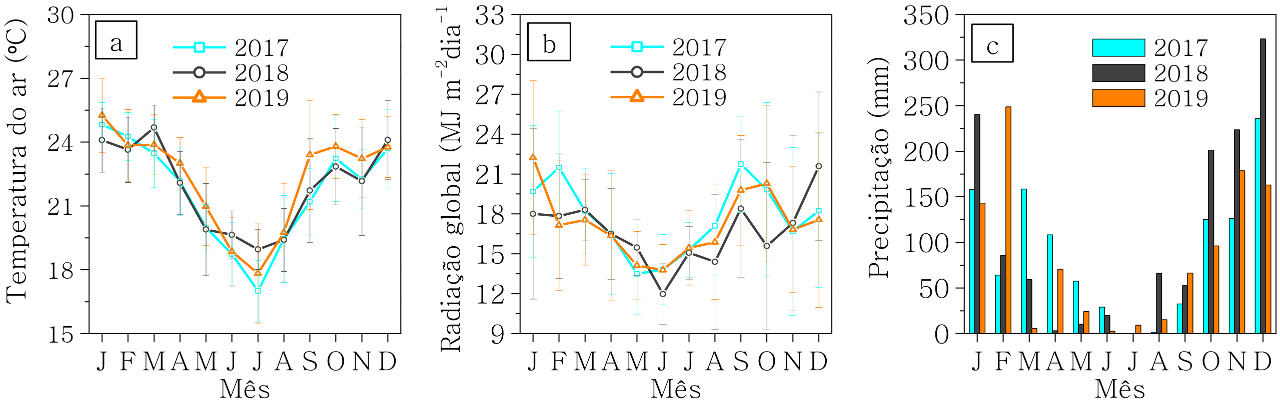

Figure 1. Monthly daily means of air temperature (a) and global radiation (b) and monthly accumulated precipitation (c) in the years 2017, 2018, and 2019.

Table 3

Yield in the first three years (2018 to 2020) according to the N-P-K percentage relative to the recommended rate for rainfed coffee farming

	Treatment				
Year	10%	70%	100%	130%	160%
2018	23.6 ± 5.38 Ab	42.6 Aa	34.9 Aa	46.0 Aa	45.7 Aa
2019	20.8 ± 3.29 Ab	48.3 Aa	41.1 Ba	50.0 Aa	51.7 Aa
2020	26.4 ± 6.27 Ab	36.9 Aa	28.8 Ab	42.0 Aa	39.7 Ba

*Lowercase letters indicate the macronutrient rate used and uppercase letters represent the year. Means followed by the same letter — uppercase in the column and lowercase in the row — do not differ from each other.

Given the criticality of crop formation with appropriate techniques, seeking high yields in the initial years following recovery through intensive pruning, this study shows the necessity for fertilization adjustments in irrigated coffee farming. Other researchers, such as Pinto et al. (2013), Resende (2019), and Villela et al. (2015), have also aimed to refine the fertilization of irrigated crops, observing optimal results with fertilization levels exceeding 100% of the recommendations for rainfed crops. In more recent research, authors like Menicucci (2020) have endeavored to adapt fertilization strategies from rainfed to irrigated crops, building upon the guidelines suggested by Resende (1999).

For coffee trees in the third, fourth, and fifth years post-recepa, a period marked by physical and physiological stress, the impact of varying fertilizer amounts applied via fertigation to the soil was notable in terms of yield (Table 3). The recovery of the coffee plants was influenced by the conditions of water and nutrient supply, leading to yield variations across the evaluated seasons.

During the period from 2018 to 2020, a clear trend of increased yield was observed with higher macronutrient rates. The year 2018 marked the first significant production year following intensive pruning. In this year, plants receiving fertigation at only 10% of the standard N-P-K rates recommended for rainfed coffee farming yielded 23 bags/ha. As macronutrient rates increased, a corresponding increase in yield was observed, peaking at 100% of the standard rate.

In 2019, the yield for the treatment with 10% of the standard rate reached 32.67 bags/ha, showing gradual increases in intermediate treatments and achieving 91.47 bags/ha at 160% of the standard rate, which is 2.8 times higher than the lowest percentage tested. The linear correlation analysis between yield and the tested N-P-K rates (Figure 2) revealed that each 1% increase in these nutrients led to a yield increase of 0.387 bags/ha. It is noteworthy that no significant yield differences were observed between the 100%, 130%, and 160% rates.

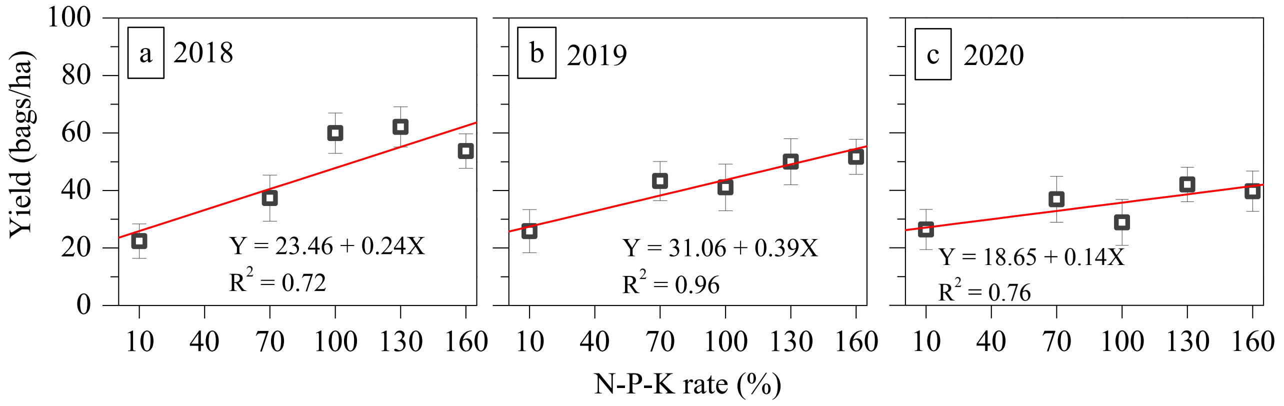

Figure 2. Yields in the first three years (2018 to 2020) after pruning as a function of the of N-P-K percentage relative to the standard rate for rainfed coffee farming.

In 2020, the lowest tested macronutrient rate (10% of the standard rate) yielded 21.91 bags/ha. Intermediate rates showed higher yields compared to the lowest rate, with the highest yield at 160%, 1.89 times greater than that observed with the lowest rate tested. However, the yield differences between the tested treatments were not significant. The linear correlation between yield and the tested N-P-K rates (Figure 2) indicated that each 1% increase in these nutrients led to a yield increment of 0.142 bags/ha, representing a much lower value than that observed in 2019.

The highest yields in the 2019 and 2020 harvests were achieved in plants treated with fertilization levels between 100% and 160%, attaining yields of 92.85 bags/ha in 2019 and 40.87 bags/ha in 2020 (Figure 2). Therefore, at least 54.0 g/plant of N (450 kg/ha N), 4.0 g/plant of P_2O_5 (33.3 kg/ha P_2O_5), and 20.0 g/plant of K_2O (166.7 kg/ha K_2O) are required for crops in the fourth and fifth year post-pruning to achieve yields within the range of 40.87 to 92.85 bags/ha (Figure 2).

Pinto et al. (2013) and Villela et al. (2015) also reported increased productivity in coffee trees fertilized with 118.33% and 122.61%, respectively, of the recommended N-P-K levels, indicating that higher fertilization levels than those recommended for non-irrigated crops are beneficial.

In a study on Robusta coffee using different drip fertigation levels (75, 100, 125, and 150% of the recommended fertilizer rate), Babou et al. (2017) explored the impact of microirrigation and drip fertigation on yield and its parameters. They found that drip fertigation with 125% of the recommended fertilizer rate resulted in higher processed coffee production. The rates reported by Babou et al. (2017) align closely with those found by Pinto et al. (2013) and Villela et al. (2015).

According to Resende (2019), varying fertilization levels from the time of seedling planting in the field leads to higher yields in (first four harvests) for crops receiving between 116% and 131% of the recommended levels for rainfed crops. When a coffee crop is established with 100% of the recommendation for rainfed coffee farming, greater productivity can be achieved if fertilization levels exceed 160% in subsequent years. However, yield increases above 130% are marginal.

Upon evaluating yields in relation to macronutrient rates each year, a decline was noted in 2020 compared to previous harvest years, irrespective of the rates tested. This outcome prompts several considerations. The first pertains to the potential occurrence of a negative biennial period in 2020. As shown in Table 3, the yield in 2019 was numerically superior compared to other years, suggesting a biennial bearing pattern. Another contributing factor could be weather conditions. Air temperatures exceeding 23 ºC throughout the year and water scarcity negatively impact coffee growth and production (Echer et al., 2010; Silva et al., 2013; Craparo et al., 2015). A water deficit affects various aspects of plant development, including anatomical, morphological, physiological, and biochemical changes (Galmés et al., 2013; Afzal et al., 2014). However, in this study, the irrigated nature of the crop negates the possibility of a water deficit being the cause of the yield discrepancy across the three harvest years. Moreover, although average air temperatures in Lavras were higher in 2019 compared to other years (Figure 1), they remained within the optimal range for the formation of the 2020 crop. It is noteworthy that, in 2020, the Arabica coffee harvest in the southern region of the state of Minas Gerais exceeded the historical average, benefiting from the positive effects of the biennial period and favorable rain and air temperature conditions (CONAB, 2020).

Scalco et al. (2011) provided further evidence of the significance of fertilizer levels in the first years of crop formation. The authors reported increased yield in super-dense irrigated coffee plantations (20,000 plants/ha) compared to rainfed crops over seven harvests. However, the researchers also observed pronounced bienniality in the productivity of irrigated crops. This biennial rhythm was similarly noted in the current study during the yield evaluations of 2018 and 2019, the first harvests post-recepa. This occurred in fertigated plants, contrasting with the typical yield increase seen in initial harvests of non-irrigated crops.

In August 2019, the analysis of the leaf paradermal section revealed no significant effect ($p>0.05$) of treatments on polar diameter of stomata, equatorial diameter of stomata, ratio between polar and equatorial diameter of stomata (PD/ED), number of stomata, and stomatal density.

However, in February 2020, the leaf paradermal section showed that the PD/ED ratio was significantly influenced ($p<0.05$) by the levels of fertilization applied. There was no significant effect ($p>0.05$) of treatments on the number of stomata, stomatal polar diameter, stomatal equatorial diameter, or stomatal density.

In February 2020 (Figure 3), PD/ED exhibited a decreasing quadratic effect, with a minimum value of 1.642 at 65% fertilization. The highest PD/ED ratio, 1.755, was observed at 160% fertilization.

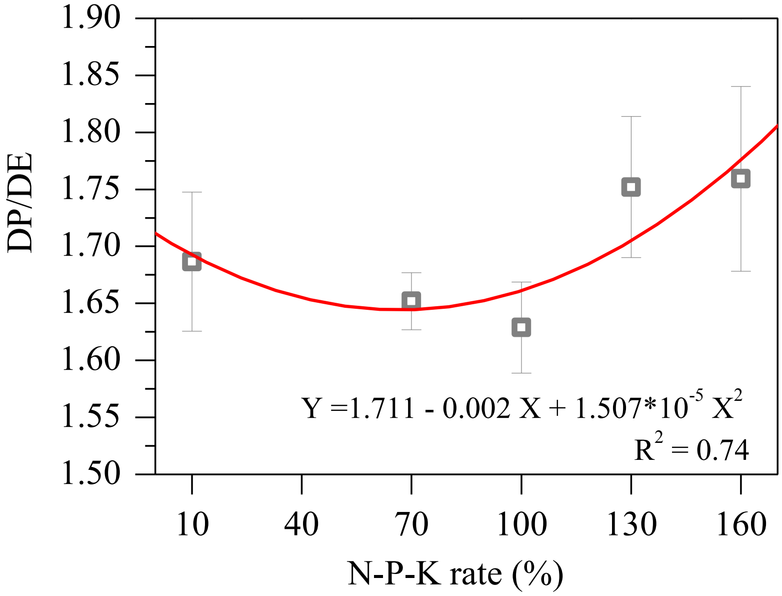

Figure 3. Ratio between polar and equatorial diameters of stomata (PD/ED) of coffee trees fertigated with different N-P-K levels in February 2020 – Experiment 2. UFLA, 2021.

A higher PD/ED ratio indicates an ellipsoid shape of the stomata (Batista et al., 2010), which can enhance gas exchange by enabling greater carbon dioxide absorption with smaller stomatal openings, thereby minimizing water loss through transpiration (Batista et al., 2010).

Menicucci (2020), assessing fertilizer levels on the anatomy and physiology of developing coffee trees, found that PD/ED ratios, also in August 2019, were higher at 122.39% and 138.62% of standard fertilization. The lowest values were observed at 45.88% and 40.04% of standard fertilization, aligning with the results of this study.

Thus, it can be inferred that fertilizer rates below the recommended level negatively affect the equatorial diameter of stomata and PD/ED ratio. In contrast, plants with balanced nutrition, that is, receiving either the recommended rate or above, exhibit a higher PD/ED ratio. This could optimize gas exchange in coffee leaves. Additionally, a higher PD/ED ratio may correlate with reduced leaf transpiration, as stomata become more elliptical (Batista et al., 2010). Similar findings were reported by Gama et al. (2017) in the same experimental area, in the first year after implementation, where the standard fertilization level at 100% N-P- K yielded a greater PD/ED ratio.

Evaluating the physiological characteristics of plants, no significant effect ($p>0.05$) was observed from varying levels of N-P-K fertilization on fertigated coffee trees in the fourth and fifth years after recepa. This lack of impact was noted in stomatal conductance, chlorophyll a index, chlorophyll b index, and total chlorophyll during the seasons of August/2019, November/2019, and February/2020.

Menicucci (2020) reported findings akin to these, specifically in the context of nitrogen metabolism and nutrient concentration in irrigated coffee trees. Their research revealed that chlorophyll a, chlorophyll b, and total chlorophyll concentrations did not significantly respond to N rates. Further, when examining the effect of different N-P-K fertilization levels on the physiology of developing coffee trees, no notable differences were detected in the chlorophyll a, chlorophyll b, or total chlorophyll indices between April and October 2019, and February 2020.

In November 2020, the study of physiological traits revealed significant effects ($p<0.05$) of fertilizer levels on the chlorophyll a index, chlorophyll b index, total chlorophyll, and stomatal conductance. Specifically, the chlorophyll a and total chlorophyll indices exhibited a quadratic pattern, peaking at approximately 120% and 125% of the standard N-P-K fertilization levels, respectively (Figures 4A and 4C). Conversely, the chlorophyll b indices showed a linear increase, with their highest points near the 160% level of standard N-P-K fertilization (Figure 4B). Stomatal conductance data displayed a decreasing linear trend, with the highest point at 10% and the lowest at 160% of the standard N-P-K fertilization (Figure 4D). These observations are in line with the findings of Reis et al. (2006), who noted an increase in chlorophyll levels in leaves corresponding to escalating nitrogen rates.

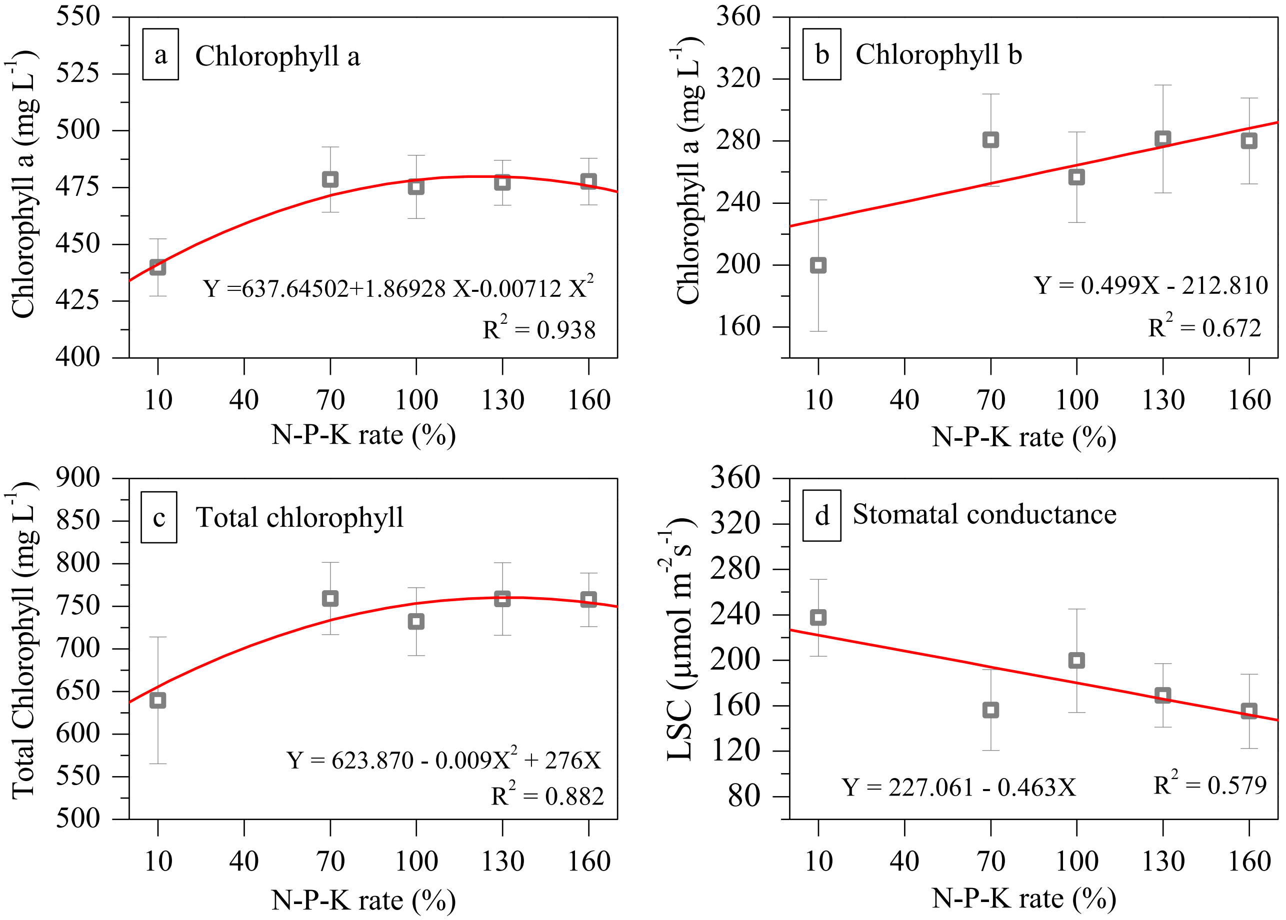

Figure 4. Chlorophyll a (A), chlorophyll b (B), and total chlorophyll (C) indices and stomatal conductance (D) of coffee trees fertigated with different N-P-K levels in November 2020.

Menicucci (2020) found higher levels of chlorophyll a, chlorophyll b, and total chlorophyll in June 2019 at fertilization levels near 100% of the standard N-P-K. Similarly, Resende (2019) worked with coffee trees in the second and third year after *recepa* pruning, in the same experimental area of the present study, and observed a linear increase in chlorophyll b and total chlorophyll contents in the leaves o coffee plants, peaking at 160% of standard N-P-K fertilization.

Moreover, Menicucci (2020) noted no significant difference in stomatal conductance due to N-P-K fertilization levels in forming coffee trees. This finding was consistent with other studies in the same experimental area albeit at other stages of coffee plant growth. These include Resende (2019), who found no significant difference in stomatal conductance in response to N-P-K levels in the first year post-*recepa*, and Gama et al. (2017), who observed no significant differences in stomatal conductance, transpiration, and photosynthetic rate under different N-P-K levels in the second year after planting.

Addressing stress conditions, Peloso et al. (2017) reported that water deficit adversely affects coffee tree photosynthesis, either through reduced efficiency in the photochemical apparatus or through significant decreases in stomatal conductance, correlating with lower net CO2 assimilation values. Taiz et al. (2017) state that leaf water potential decreases as soil dries, with rehydration reversing this effect. Consequently, periods of higher rainfall distribution would correlate with greater leaf water potential compared to times of water scarcity.

However, the present study found no differences in stomatal conductance across various fertilization levels, possibly due to minimal soil moisture variation within the experimental plots during the evaluated seasons, as it was a fertigated area.

Conclusions

Achieving higher productivity post-*recepa* pruning necessitates at least 100% of the standard production fertilization, which can yield up to 93.05 bags/ha. To attain yields around 93.05 bags/ha, a minimum of 54.0 g/plant of N (equivalent to 450 kg/ha N), 4.0 g/plant of P_2O_5 (33.3 kg/ha P_2O_5), and 20.0 g/plant of K_2O (166.7 kg/ha K_2O) are required. Plants with balanced nutrition — that is, receiving the recommended fertilizer rate or above it — exhibit a larger ratio between the polar and equatorial diameters of the stomata, a characteristic that potentially optimizes gas exchange in the leaves of the coffee plants.

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