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Initial performance of coffee trees with different fertilization and irrigation management

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ABSTRACT

Coffee is one of the main agricultural commodities in the world. However, due to its sensitivity to water stress and changes in the availability of finite sources of nutrients and the constant search for a more sustainable agriculture, it is necessary to modulate the responses of plants to soil water and the real nutritional demand of the coffee tree. Thus, the objective of this work was to analyze the initial performance of arabica coffee grown with or without water restriction and with five different soil fertilization managements, in order to propose more techniques to optimize coffee production. The experiment was carried out in a greenhouse, in the experimental area of the Federal University of Viçosa, in the city of Viçosa-MG. The experimental design was completely randomized in a 2x5 factorial scheme, with two irrigation depths (40% and 80% of the available water in the soil) and five fertilization managements (conventional 100% of the recommended dose, controlled release of 80 and 100% of N and recommended K and organomineral 80 and 100% N and K of the recommended dose). In view of the observed results, it can be observed that water restriction in the initial period of coffee development provided a reduction in the variables of root and shoot growth of the plants, regardless of the soil fertilization management used. In environments with greater water restriction, no significant difference was observed between the studied fertilizers and in an environment without water restriction, the controlled release fertilizer 80% presented the highest global growth averages. Water management provided a greater effect on coffee nutrient dynamics than duly studied fertilization management.

Key words: *Coffea arabica* L.; Coffee nutrition, sustainability, water deficit.

1 INTRODUCTION

The availability of water is essential for plant growth and stands out as one of the most limiting abiotic factors for coffee growth and development (Pizzeta et al., 2016; Rodrigues et al., 2016; Ribeiro et al., 2018; Ribeiro et al., 2019). Considering that modern agriculture is increasingly prone to scenarios of rising temperatures, increased periods of drought (summer), as well as reduced water availability (Vicente et al., 2015; Martins et al., 2016; Colodetti et al., 2020; Moreira et al., 2021), the study of agronomic techniques that can minimize these impacts on plant production is of fundamental importance for modern agriculture.

In coffee plants, the water deficit already causes significant losses in the productivity and quality of the coffee produced in the world (Ribeiro et al., 2019; Miranda; Drumond; Ronchi, 2020; Scwan et al., 2020; Constantino et al., 2021; Santos et al., 2021; Soares et al., 2021; Ferreira et al., 2021a). This reduction in productivity may occur directly by dehydration of the photosynthetic apparatus of plants, or by the indirect effect of stomatal closure (Taiz et al. 2017; Souza et al., 2020). It is also noteworthy that water stress directly affects the absorption of nutrients in plants, since the availability of the most essential nutrients for the growth and development of coffee plants is regulated by the movement of water in the soil and by the availability of these nutrients in the root system (Martinez et al., 2020; Souza et al., 2020).

It is also noteworthy that coffee is a plant sensitive to nutritional imbalances and that most mineral sources used in agriculture come from finite resources that demand high energy expenditure and require large financial investment for their extraction (Martinez; Neves, 2015; Dias et al., 2015; Pantano et al., 2016). Thus, research that allows greater productive efficiency of plants due to the lower application of finite mineral sources has been strongly encouraged (Tomaz et al., 2011; Amaral et al., 2011; Machado et al., 2016; Martins et al., 2019). Thus, studies of techniques capable of maximizing agricultural production and minimizing nutrient losses are of fundamental importance for the sustainability of the coffee enterprise.

As highlighted in the literature, nutrient losses by leaching, volatilization and adsorption on soil colloids are common in current agricultural crops worldwide (Diaz et al., 2015; Pantano et al., 2016; Azad et al., 2020; Pham et al., 2020; Glab et al., 2020; Messiga et al., 2020; Fletcher et al., 2021; Hamidi et al., 2021). Such losses bring direct impacts to the environment, whether by the emission of N2 into the atmosphere due to ammonia volatilization (Volpi et al., 2017), pollution of underground water sources by leaching of nitrate and potassium (Zhao et al., 2006;; Lawniczak et al., Al., 2016), soil salinization (Fan et al., 2020; Farooq et al., 2021) or indirect pollution by the use of high energy sources for extracting and transporting fertilizers (Yuan et al., 2020; Fang et al., 2021), so that studies aimed at minimizing such losses are of fundamental importance for modern agriculture (Cano-Ruiz et al., 2020; Bia; Kang; Wan, 2020; Glab et al., 2020; Azad et al, 2020).

Furthermore, fertilizers with greater efficiency tend to stand out as an efficient alternative for plant nutrition in adverse situations. According to Timilsena et al. (2015) and Araújo et al. (2020), the use of controlled-release fertilizers is more efficient in supplying nutrients to plants, due to their gradual availability, in addition to allowing the reduction of losses by leaching and volatilization, making the fertilization of crops safer and more sustainable.

Thus, considering the hypothesis that the coffee tree presents different responses regarding the management of fertilization and water availability, the objective of this work was to analyze the initial performance of Arabica coffee cultivated with or without water restriction and with five different soil fertilization managements to propose optimizing techniques for the initial growth of coffee plants.

2 MATERIAL AND METHODS

The experiment was carried out in a greenhouse in the experimental area of the Department of Agronomy of the Federal University of Viçosa, located in the municipality of Viçosa - MG (20° 45'14"S and 42° 52'54" W) at an altitude of 649 meters.

The soil used was collected from a depth of 10 to 40 cm, discarding the first 10 cm of the profile to reduce the effect of organic matter present in the surface layer, and a sample of this was sent to the laboratory to carry out the analysis of its chemical attributes (Table 1).

Table 1: Soil chemical attributes.

Soil chemical attributes[1]									
pH	P	K	Ca	Mg	Al	SB	CTC	V	MO
	Mg/dm³				Cmolc/dm³			%	dag/kg
5.13	43.4	159.0	2.96	0.69	0.00	4.06	4.06	52.3	2.11

[1] Extraction and determination: pH in water; P, K, Na: Mehlich, extractor and determination by colorimetry; Ca, Mg, Al: KCl mol L^{-1} extractor and determination by atomic absorption spectrometry; H+Al: 0.5 mol L^{-1} Calcium Acetate Extractor; Organic Matter: wet carbon oxidation with potassium dichromate in an acidic medium (H_2SO_4).

After characterization, the entire volume of soil was dried in the shade and homogenized in a sieve with a mesh of 2.0 mm and then separated into volumes of 10 dm³, by weighing on a precision scale, and packed in plastic containers with a capacity of 12 dm³. Subsequently, the soil was properly corrected and fertilization carried out according to the coffee tree's needs in a protected environment, in accordance with the recommendations proposed by Malavolta (1981).

Arabica coffee seedlings, cultivar Mundo Novo IAC 379/19, were planted with four pairs of leaves and periodically irrigated, raising soil moisture to field capacity, for a period of 30 days, in order to ensure uniformity and full establishment of the plants. plants.

After 30 days of adaptation, irrigation water was added gravimetrically according to the difference in weight of the plastic container, in an electronic scale, submitting the soil to field capacity. For this, all plastic containers with established coffee plants were saturated with water and subjected to free drainage for a period of 48 hours. After this period, each experimental plot was weighed and thus defined the soil moisture, corresponding to the field capacity of the pots.

The experimental trial used was in a 5x2 factorial scheme, corresponding to five fertilization managements and 2 water managements, arranged in a completely randomized experimental design, with 4 replications, with the experimental plot represented by one plant per pot.

The water regimes consisted of treatments with and without water restriction (water replacement when the soil had 40% and 80% of the water available at field capacity, respectively) and soil fertilization managements were composed by the use of conventional fertilizer (300 mg/kg of N and 150 mg/kg of K), organomineral 80% (240 mg/kg of N, 120 mg/kg of K and 17% of total organic carbon), organomineral 100% (300 mg/kg of N; 150 mg/kg of K and 17% of total organic carbon), controlled release 80% (240 mg/kg of N and 120 mg/kg of K) and 100% controlled release (300 mg/kg of N and 150 mg/kg of K). To standardize the experimental tests, the choice of fertilizers was made so that all nitrogen sources were ammonium sulfate and potassium sources were potassium chloride.

To establish irrigation, in the late afternoon of every two days, all experimental plots were weighed in an electronic scale, with a capacity of 25 kg, and variation of 0.5 g. The plots referring to treatments with and without water restriction were irrigated with the amount of water lost by transpiration and had the soil moisture returned to the moisture corresponding to the field capacity whenever they reached the proposed levels.

After 190 days of cultivation, as proposed by Hinnah et al., (2014), the stem diameter (mm) was measured in the region of the plant's neck, determined with the use of an electronic caliper, the chlorophyll index, determined with the using the SPAD 502® chlorophyllometer, the length of the first plagiotropic branch, the plant height and the number of plagiotropic branches were counted.

Then, the plant stems were sectioned, separating the stem from the roots. The roots were separated from the soil, washed and dried in the shade. Then, a length of 5.0 cm was marked on a sheet of E.V.A (Satin Vinyl Foam) with chalk, serving as a reference measure for the analysis of the root system in the Safira software. Then, the root system of all experimental units was photographed and these images were launched in the Safira software, which provided data on weighted diameter, length, volume and root surface area.

For the determination of plant biomass (root dry mass and shoot dry mass), the roots and shoots were placed in paper bags and placed in a forced circulation oven at 65 °C until constant mass. The nutritional analysis of the coffee tree was also carried out by collecting leaves from the middle third of each plant. After collection, the samples were placed in paper bags and sent for analysis in the laboratory, obtaining the levels of foliar nutrients.

Data were subjected to analysis of variance, when a significant difference was observed ($p \leq 0.05$), means were compared by Tukey's test ($p \leq 0.05$). To verify the dispersion of treatments and their associations with the morphological and nutritional traits of the plants, a hitmap analysis was performed, associated with a cluster analysis considering the Mahalanobis distance and principal components, through the analysis of the graphical dispersions of the scores of the treatments, being recommended the first two main components, which explain more than 60% of the total variation of the data (Ferreira, 2018). Statistical analyzes were performed using R free software (R Core Team, 2021).

3 RESULTS

Regardless of the fertilizer used, it is observed that the coffee tree subjected to the water regime without water restriction (L80) had higher averages of plant height (Figure 1A), stem diameter (Figure 1B), root dry mass (Figure 1C) and total dry mass (Figure 1D) compared to that with restriction (L40) (Figure 1). It is also observed that the organic-mineral fertilizer 80% (T3) and the organic-mineral 100% (T2) were the ones that presented the smallest accumulations of root and total dry mass (Figure 1C and D) regardless of the analyzed water regime.

By analyzing the stem diameter variable (Figure 1B), it is possible to observe that the management of soil fertilization with organomineral fertilizer at 100% of the recommended dose (T2) provided greater response when subjected to water restriction (L40) and controlled release 80% of the recommended dose (T4) the smallest values of stem diameter for the same treatment.

Based on the results obtained, it can also be verified that water restriction provided the lowest responses for the traits of root volume (Figure 2A), root surface area (Figure 2B), root length (Figure 2C) and dry mass of the root (Figure 2D), when compared to treatment without restriction (Figure 2). However, it is noted that the variable root volume (Figure 2A) in water management with restriction and root length (Figure 2B) in water management without restriction, did not obtain statistical difference between fertilizers.

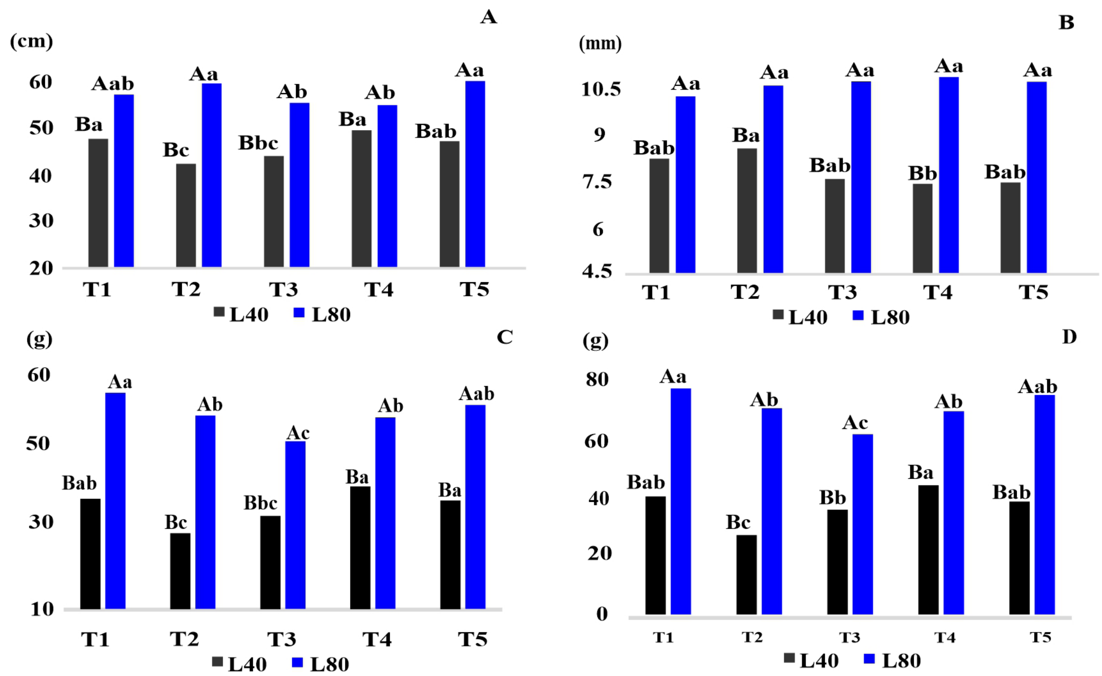

Figure 1: Means of plant height (A), stem diameter (B), shoot dry mass (D) and total dry mass (D) traits of young coffee trees subjected to a deficit associated with 40% of available water in the soil (L40) and 80% of the water available in the soil (L80) and fed with conventional fertilizer (T1), 100% organomineral (T2), 80% organomineral (T3), 100% controlled release (T4) and controlled release 80 % (T5). Means followed by the same capital letter between water regime and lower case between fertilization managements, do not differ by Tukey test at 5% probability.

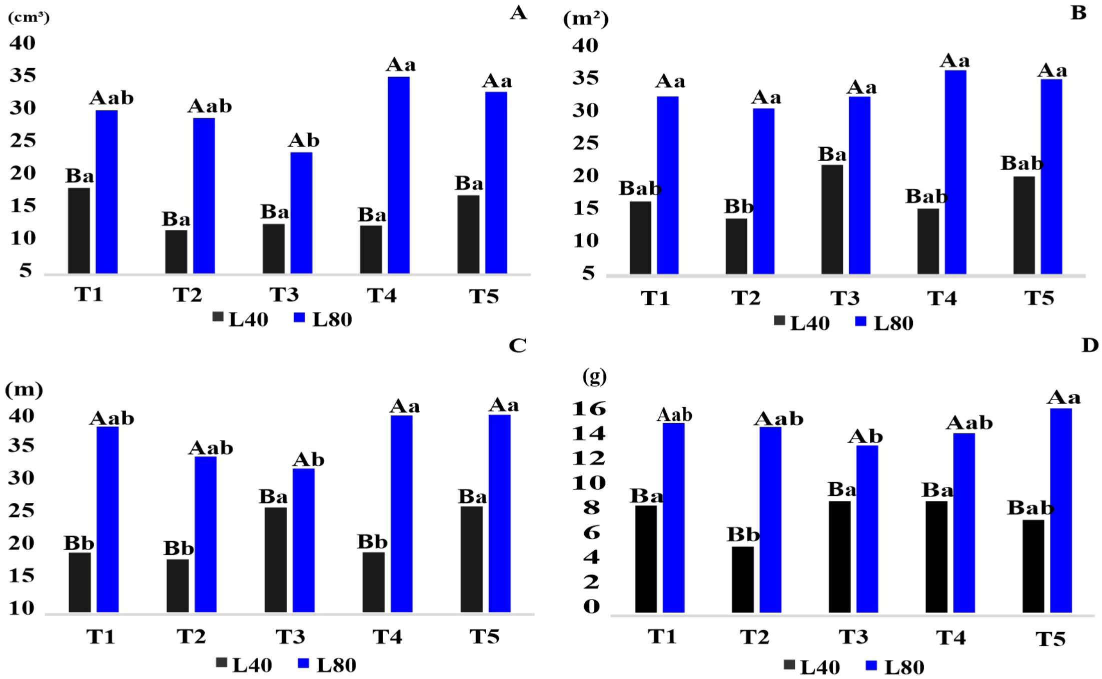

Figure 2: Means of root volume (A), root surface area (B), root length (C) and root dry mass (D) of a young Arabica coffee plant subjected to a deficit associated with 40% of water available in the soil (L40) and 80% of the water available in the soil (L80) and fed with conventional fertilizer (T1), organic mineral 100% of the recommended dose (T2), organic mineral 80% of the recommended dose (T3), controlled release of 100% of the recommended dose (T4) and controlled release of 80% of the recommended dose (T5). Means followed by the same uppercase letter between water regimes and lowercase between fertilization managements do not differ by Tukey test at 5% probability.

When interpreting Figure 2, it is possible to observe that the organomineral fertilizer with 80% of the recommended dose (T3) in water management with water restriction (T40) had the largest root mean surface area (Figure 2B) root length (Figure 2C)) and root dry mass (Figure 2D) and the smallest mean except root length (Figure 2B) for the other variables when analyzing unrestricted water management (T80).

Based on the graphic dispersion of the first two main components associated with the five soil fertilization managements and the two water managements, it is possible to observe that the first two main components were able to explain 95.7% and 67.7% of the total variation of the data for growth (Figure 3A) and nutritional (Figure 3B) traits, respectively.

Therefore, it is possible to infer that this dispersion reliably explains much of the total variation of the data under study (Ferreira, 2018), without significant losses in the biological behavior of plants (Cruz; Regazzi; Carneiro, 2012; Barbosa et al., 2019; Ferreira et al., 2021a).

Based on the graphical dispersions, it is possible to see that, for both the growth traits (Figure 3A) and the nutritional traits (Figure 3B), there was the formation of 4 groups and that the fertilization management groups within each water restriction prevailed graphically less dispersed.

For the growth traits (Figure 3A and Figure 4A), it is noted that controlled-release fertilizers 80% and 100% (T5S and T4S) prevailed close, well associated with the chlorophyll variable and little associated with the other growth variables (Figure 4A), while management with conventional fertilizer (T1S), 80% organomineral (T3S) and 100% organomineral (T2S) showed a low association with the growth variables.

On the other hand, when analyzing coffee tree responses to different fertilization managements when there was no water restriction, it is clear that, with the exception of 80% organic mineral fertilizer (T5I), all other soil fertilization managements prevailed within the same group (Figure 3A and Figure 4A). This greater association occurred because conventional fertilizer (T1I), 100% organomineral (T2I), 80% organomineral (T3I) and 100% controlled release (T4I) were more associated with the growth variables and had low correlation with the variable chlorophyll, while the organomineral 80% (T5I) in addition to presenting a good correlation with the growth variables, presented a good correlation with chlorophyll.

For the nutritional variables, it is noted that in the water regime without water restriction, a single group was formed with all nutritional managements (Figure 3B and Figure 4B), while for the water regime with water restriction there is proximity between the conventional ones. fertilizers (T1S), organomineral with 80% of the recommended dose (T2S) and organomineral 100% of the recommended dose (T3S) forming a group, and the other two fertilizers that were well separated.

In Figure 4B, it can be seen that in the regime without water restriction, the plants, regardless of the fertilization studied, showed an inverse association with nitrogen (N) and null association with copper (Cu) and phosphorus (P). The management of conventional (T1I) and 80% organomineral (T3I) fertilization showed greater association with sulfur than other fertilizers for this water regime and the lower fertilization management and nutritional management with 100% controlled release and 100% organomineral fertilizer showed greater association with potassium (K) than the other treatments of the irrigated regime.

On the other hand, nutritional management when the coffee tree was subjected to water restriction resulted in the formation of 3 groups (Figure 4B), the first group being formed only by 100% controlled-release fertilizer (T4S), which showed a good association with zinc. (Zn) and low association with phosphorus (P) and potassium (K) (Figure 4). The second group (Figure 4B) was formed by the controlled-release fertilizer 80% (T5S), which showed a good association with copper (Cu), magnesium (Mg), calcium (Ca) and sulfur (S) in addition to a low association with boron (B) (Figure 4). The third group was formed by the other fertilizers (T1S, T2S, T3S) which, in turn, generally had a low association with micronutrients and no association with most macronutrients.

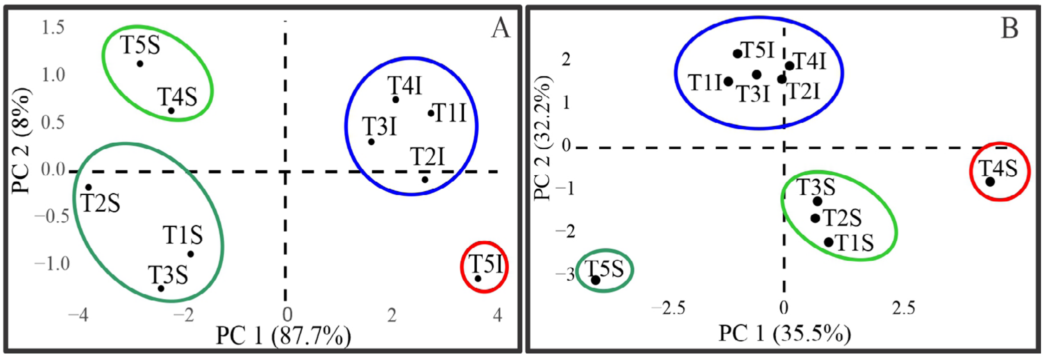

Figure 3: Scatter diagram in relation to the first two main components referring to the five soil fertilization managements (*) associated with the growth (A) and nutritional (B) traits in two water regimes.

* (T1I and T1S) conventional fertilization, submitted to a deficit associated with 80% and 40% of the available water in the soil, respectively; (T2I and T2S) organomineral fertilizer with 80% of the recommended dose submitted to 80% and 40% of the available water in the soil, respectively; (T3I and T3S) organomineral fertilizer with 100% of the recommended dose, submitted to 80% and 40% of the available water in the soil, respectively; (T4I and T4S) controlled release fertilizer with 80% of the recommended dose, submitted to 80% and 40% of the available water in the soil, respectively; (T5I and T5S) controlled-release fertilizer with 100% of the recommended dose, subjected to 80% and 40% of available soil water, respectively.

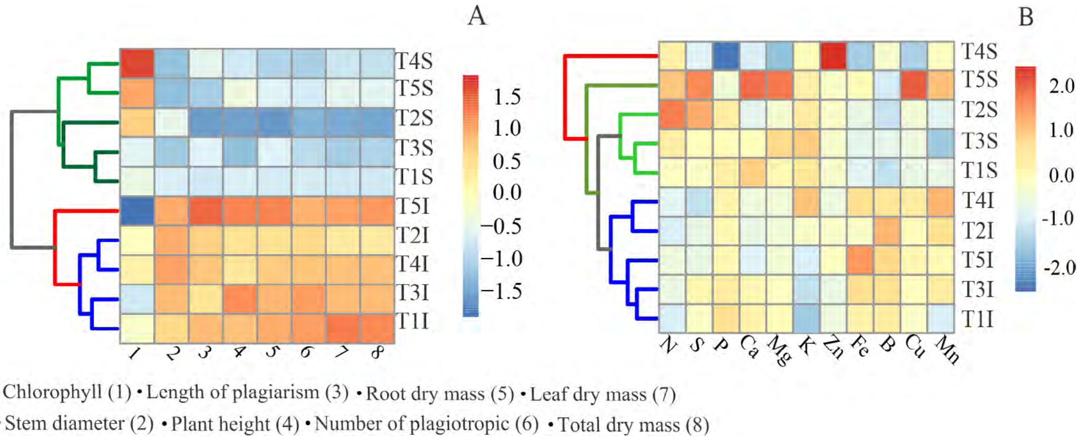

Figure 4: Heatmap and hierarchical dendrogram referring to five soil fertilization managements (*) associated with growth (A) and nutritional (B) traits in two water regimes.

* (T1I and T1S) conventional fertilization, submitted to 80% and 40% of the available water in the soil, respectively; (T2I and T2S) organomineral fertilizer with 80% of the recommended dose submitted to 80% and 40% of the available water in the soil, respectively; (T3I and T3S) organomineral fertilizer with 100% of the recommended dose, submitted to 80% and 40% of the available water in the soil, respectively; (T4I and T4S) controlled release fertilizer with 80% of the recommended dose, submitted to 80% and 40% of the available water in the soil, respectively; (T5I and T5S) controlled-release fertilizer with 100% of the recommended dose, subjected to 80% and 40% of available soil water, respectively.

4 DISCUSSION

Irregular water distribution provides agricultural crops with periods of accentuated deficit, which can lead to reduced productivity, damage to plant growth and stand establishment, in addition to irreversible damage to plant metabolism. (Pinto et al., 2008; Bragança et al., 2016; Martins et al., 2019; Colodetti et al., 2020; Ferreira et al., 2021b; Moreira et al., 2021; Chemura et al., 2021) especially when it comes to the initial stage of its development. (Rodrigues et al., 2016; Pizzeta et al., 2016; Ribeiro et al., 2018, Ribeiro et al., 2019).

Thus, studying the effects of water restriction on the initial growth of Arabica coffee as a function of different fertilization managements, it was possible to observe that water restriction provided the coffee tree with less accumulation of roots and aboveground biomass, regardless of the fertilization strategy used (Figure 1 and Figure 2). Such behavior is possibly due to physiological factors that are triggered in the plant due to water deficit (DaMatta; Ramalho, 2006; Cantuário et al., 2015; Ribeiro et al., 2019; Venancio et al., 2020), such as the synthesis of ethylene, abscisic acid, reduced auxin synthesis and reduced photosynthetic rate (Cantuário et al., 2015; Taiz et al., 2017), which significantly promote the reduction of plant growth and development.

Corroborating this information, Silva et al. (2008) point out that when in water deficit, analyzing the plant's behavior from a physiological point of view, the first adaptive defense strategy is water restriction, which in turn is related to early stomatal closure, with the purpose of pulping water of soil, to prolong its survival (DaMatta; Ramalho, 2006, Cantuário et al., 2015; Ribeiro et al., 2019), this characteristic however is related to a reduction in photosynthetic rates and, consequently, a reduction in growth of plants (Taiz et al., 2017).

It is also observed, based on the analysis of Figure 1, that soil fertility management with 80% organomineral fertilizer (T3) and 100% organomineral fertilizer (T2) were the ones with the lowest accumulation of roots and dry mass total (Figure 1C and D) regardless of the water regime studied. As highlighted by Araújo et al. (2020), organomineral fertilizers present the incorporation of nutrients in their mineral form together with organic matter, which tends to reduce nutrient losses by leaching and adsorption in the soil (Souza et al., 2014; Ciesielczuk et al., 2019 Araújo et al., 2020), in addition to incorporating these nutrients into the soil matrix more slowly and gradually, nourishing the plant for longer (Araújo et al., 2020).

This slower feeding may justify the lower response of the coffee tree to this fertilizer found in this study, since this is an initial development of the coffee tree and the vegetative and nutritional status of the plants was evaluated for a short period of time, the offer of fertilization with organomineral fertilizer was possibly not enough to meet all the nutritional demand of the coffee tree in the interval studied in this work.

However, when analyzing the stem diameter variable (Figure 1B) it is possible to observe that when the plants were subjected to water restriction, the best response for stem diameter came from the treatment with 100% organomineral fertilization (T2). It is also observed through the analysis of Figure 1 that for the nutritional management with controlled-release fertilizer with 80% of the recommendation (T5), all the growth variables did not differ statistically from the nutritional management with 100% of the fertilization recommendation in both water regimes studied.

Such a result can be an alternative for the sustainability of the coffee enterprise, since, fundamentally, most of the sources of mineral fertilizers used for plant nutrition are finite sources and/or that demand great energy expenditure for their extraction. (Cordell et al., 2011; Peixoto Filho et al., 2013; Pantano et al., 2016; Smith; Gilbertson, 2018; Voronkova et al., 2020). Thus, it is observed that the use of soil fertility management with controlled-release fertilizer using 80% of the total recommended dose of nutrients was able to maintain adequate nutrition during the initial period of coffee growth for the conditions under study, which leads to the interpretation that the use of the full dose for controlled-release fertilizers is possibly associated with the consumption of luxury nutrients in the coffee tree (Römheld, 2012).

The nutrient uptake curve in plants is associated with three distinct zones, as described by Römheld (2012), the zone of deficiency, sufficiency and toxicity. Luxury consumption is associated with the sufficiency range, where although soil nutrient levels do not necessarily cause toxic damage to the plant, this is not directly related to growth and productivity gains (Römheld, 2012; Wadt et al., 2012).

The soil fertility management with organomineral fertilizer with 80% of the recommended dose (T3) provided the highest averages for the traits of the roots when under water restriction and the lowest averages among the soil fertilization managements for the unrestricted regime. This behavior can be explained by the greater investment in root provided by the coffee tree for this treatment (T3) due to the slower and gradual release of mineral nutrients from the fertilization (Araújo et al., 2020), which was maximized by the lower water availability.

According to Marschner (1995) and Taiz et al. (2017) when the plant is in an environment with nutritional and/or water limitations, it tends to increase the synthesis of abscisic acid in the roots, which drives the growth of the root system. This plant defense mechanism can provide greater exploration of the soil profile by the roots, which allows greater absorption of water and nutrients by plants (Marschner, 1995; Nakamura et al., 2004; Epstein; Bloom, 2006; Taiz et al., 2017).

The concept of nutritional efficiency is related as well as the response of the Arabica coffee plant to the management of soil fertilization (T3), since the most efficient plants are those with the best capacity to absorb water and nutrients. Uptake rates are directly related to the aggressiveness of the root system in the exploration of large volumes of soil (Fageria, 1998; Amaral et al., 2011; Tomaz et al., 2011; Martins et al., 2016).

Through the multivariate analysis of the treatments for the growth variables (Figure 3A and Figure 4A) a good association can be observed between the treatments resulting from the management of soil fertilization with controlled release fertilizers in a water regime with water restriction (T4 and T5) with the chlorophyll variable, as well as a low association of the other treatments with the other growth variables (Figure 4A).

This low association with growth variables was expected, since, as a defense mechanism against water stress, the coffee tree tends to reduce its vegetative growth (Silva et al., 2014; Rodrigues et al., 2016; Pizetta et al., 2016; Ribeiro et al., 2018; Ferreira et al., 2021b). As described above, the stomatal closure mechanism is efficient in reducing plant water losses to the atmosphere (Silva et al., 214), but this defense against stress provides a reduction in plant growth and development, which can cause serious productivity losses (Pizetta et al., 2016; Ribeiro et al., 2018; Ribeiro et al., 2019).

On the other hand, when there was no water restriction, it is clear that, with the exception of organomineral fertilizer at 80% of the recommended dose (T5I), all other soil fertilization managements prevailed within the same group (Figure 3A and Figure 4A). This greater association between soil fertilization managements possibly occurred due to the greater association of the treatments tested for water management without water restriction with the growth variables.

In general, we can associate that although there was a difference between the soil fertilization managements, the grouping of variables was more directly affected by the water regime than particularly by the soil fertility. However, it is still possible to observe a greater association between treatments related to controlled release 80% and conventional fertilizers with the variables root, shoot and total dry mass, associating these treatments as the most promising for the regime without water restriction.

It is noteworthy that one of the biggest problems associated with fertilizer management is related to nutrient losses. Nitrogen losses in tropical agriculture occur predominantly through the phenomenon of volatilization, and these conditions are significantly affected by edaphoclimatic conditions, especially soil moisture (Tasca et al., 2011; Dominghetti et al., 2016; Ciesielczuk et al., 2019.

Phosphorus, in turn, is strongly adsorbed by soil colloids (Prochnow; Peterson; Bruulsema et al., 2019) and its mobility in the soil is low, occurring predominantly by diffusion (Malavolta, 2006), and the soil water content can favor the availability of the nutrient for the plant and reducing its adsorption by soil colloids (Novais; Smyth, 1999) supporting the behavior presented by these treatments.

As for the growth variables, the treatments refer to different soil fertilization management without being conditioned to water deficit, the nutritional variables were grouped into a single group (Figure 3B), which, in turn, showed a low association with the nitrogen. As highlighted by Marschner (1995), Epstein and Bloom (2006), Nunes et al. (2013) and Martinez et al. (2015), nitrogen is one of the nutrients most in demand by the coffee tree, and it acts significantly in the biosynthesis of proteins and chlorophylls, as well as in the synthesis of the leaf area and production of dry mass. Thus, taking into account that plants that were not water-restricted had greater accumulations of dry mass compared to the water-restricted regime (Figure 1 and Figure 2), we can assume that this lower association with nitrogen occurred due to greater use and converting. o in dry mass.

5 CONCLUSIONS

The water restriction in the initial period of coffee development provided a reduction in the growth variables of the roots and shoots of the plants, regardless of the soil fertilization management used.

In environments with greater water restriction, no significant difference was observed between the studied fertilizers and in an environment without water restriction, the controlled release fertilizer 80% presented the highest overall growth averages.

Among the treatments studied, the use of controlled-release fertilizers was shown to be potential, as it can reduce labor and machinery costs and, therefore, the possible effects of soil compaction in coffee plantations.

The water management provided greater effect on the nutrient dynamics of the coffee tree than the duly studied fertilization management.

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7 AUTHORS' CONTRIBUTION

JGSV and IPP wrote the manuscript and performed the experiment, DTC and DSF supervised the experiment, co-worked the manuscript and performed all statistical analyses, and DTC reviewed and approved the final version of the work.

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