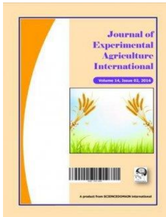

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Limitation of Relative Transpiration and Growth of Arabic Coffee in Response to Water Deficit

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Authors' contributions

This work was carried out in collaboration between all authors. Authors WRR, MSG, AAP, VAC and DSF developed the experiment, performed the statistical analysis of the data and wrote the first draft of the manuscript. The author and professor EFR actively participated in the design of the project, orientation of the execution stages and elaboration of the data, being also responsible for the correction of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this study was to evaluate the limitation of transpiration and growth of arabica coffee plants as a function of the reduction of water availability through the methodology of the fraction of transpirable soil water (FTSW). The study was conducted in a greenhouse of the Center of Agrarian Sciences and Engineering of the Federal University of Espírito Santo, located in the municipality of Alegre, Espírito Santo State, Brazil, with coordinates 20º45' S, 41º32' W and altitude of 269.0 m, in a factorial scheme 3x2, being the period of induction of the water deficit in three periods (P1= at 45 days after planting, P2= at 75 days after planting and P3= at 105 days after planting) and replenishment of water in the soil on two treatments (T0- without water deficit and Td-

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water deficit induced until the plants reach 10% of the relative transpiration of the T0 treatment), in a completely randomized design with eight repetitions. The following variables were evaluated: relative transpiration (RT), mean leaf area (MLA) and mean plant height (MPH). It was concluded that the younger the plants are subjected to water deficit, the more sensitive they are to the effects of the phenomenon, and the first variable to be affected by the deficit is MPH. With the plant's maturation, there was a gradual gain of resistance, which in some cases resulted in responses between treatments statistically equal.

Keywords: FTSW; Coffea arabica; water resources; irrigation management.

1. INTRODUCTION

The coffee is one of the most valuable commodities marketed, leaving behind only petroleum [1]. According to the National Supply Company - CONAB (2018), Brazil remains the world's largest producer and exporter of coffee. The estimate for the 2018 harvest a volume of 58.5 million bags (60 kg) benefited, in a total area of 2,202.6 million hectares [2].

The area planted witch arabica coffee corresponds to 81% of the existent area with coffee plantations and represents approximately 76% of the country's total production, estimated from 41.74 to 44.55 million bags for the 2018 harvest [2]. The State of Minas Gerais stands out as the most significant national producer of this commodity with an area of 1.23 million hectares and an estimated production between 29.1 and 30.6 million bags [2].

According to Arruda [3], an increase is expected in the frequency and intensity of drought periods in the near future, as a consequence of climate change, causing substantial losses in agricultural areas. Drought is the problem that has most affected the Brazilian coffee-growing, putting at risk the predictions of future crops [4], and it is essential to improve techniques that aim to minimise the effect of this phenomenon.

The water deficit frequently occurs during the coffee cycle and may have a considerable negative impact on crop growth [5]. During these periods, several physiological processes occur [6,7], such as the reduction of the turgescence of the cells causing a decrease in the water potential and the decrease of the stomatal conductance, blocking the influx of CO_2 affecting the accumulation of photoassimilates, both lead to inhibition of cell growth, photosynthesis and productivity [8,9].

Some physiological characteristics contribute to the tolerance of arabic coffee to droughts, such as the maintenance of foliar turgescence, regulation of the water use rate, soil water extraction efficiency, mitigation of the simplasto volume reduction and delay of the onset of foliar deficit [10]. The coffee follows the photosynthetic pathway of the C3 cycle with productivity, growth and production of plant biomass-dependent on carbohydrates produced by photosynthesis [11]. The plant ability to produce these carbohydrates depends directly on the supply of nutrients, especially nitrogen [12,13] and water availability. Studies about irrigation levels and nitrogen rates in coffee showed that high nitrogen rates are effective when it has high water availability [14,15]. This indicates that the limitation of the water resource, causes losses both in the photosynthetic processes as well as in the capacity of nutrients absorption by the plants, due to the direct effect of this in the solution of nutrients in the soil [16].

To minimize the effects of drought, the irrigation scheduling becomes essential to promote growth, increasing economic income [17]. Studies conducted in the region of the Brazilian Cerrado showed that the irrigation during the flowering period guaranteed the ripening of the fruits, providing an estimated 1.8 million bags benefited [2]. However, estimating crop water requirements is a key factor for the correct application of the technique, in order allow to supply the demand of each species in its respective phenological phases and to make the rational use of water resources.

The fraction of transpirable soil water (FTSW) indicates the actual volume of water that can be extracted by plants, per unit of area, and in a certain moment, in relation to the total available soil water. It is an index used to evaluate the water requirement of each crop and can be used to estimate irrigation depth and to express the effect of soil water deficit on transpiration and growth variables, allowing the detection of critical FTSW, when it occurs the start of stomatal closure and decreased growth capacity [18,19]. It is the concept that most closely approximates as an indicator of the actual amount of water in the soil that can be extracted by plants for transpiration [20].

Several authors report the use of the methodology as Araujo et al. [21,22] for the coffee Arabica and Conilon, Lago et al. [19] for potato, Pinheiro et al. [23] for cassava, Ramos and Martínez-Casasnovas [24] in grapevine, Kelling et al. [25] for chrysanthemum and Ribeiro et al. [26] of coffee conilon variety diamante. However, in the literature different critical FTSW values are found, a consequence of soil, climate and crop variations [27]. Thus, the objective of this study was to quantify the influence of soil water deficit on transpiration and on the growth variables for arabica coffee plants, variety IAC 144.

2. MATERIALS AND METHODS

The study was carried out in a greenhouse at the Center of Agrarian Sciences and Engineering of the Federal University of Espirito Santo (CCAE/UFES), located in the municipality of Alegre, Espirito Santo State, Brazil (20º45' S, 41º32' W and altitude of 269.0 m) with *Coffea arabica*, 'IAC-144'.

The experiment was set up in a 3x2 factorial scheme, the induction of the water deficit was applied during three different periods (P1 = at 45 days after planting, P2 = at 75 days after planting and P3 = at 105 days after planting) and the replacement of water at two treatments (T0 = control, irrigated throughout all period of the experiment and Td = water deficit induced until the plants reached 10% of the relative transpiration of the T0 treatment), with 8 replications, being 4 replicates destined to the study of critical FTSW values and 4 repetitions destined to evaluate the recovery of the plants after the soil water deficit.

Each experimental pot portion, with 12 liters, was coated with white paper to reduce the absorption of solar radiation minimizing the heating of the soil. The soil used as substrate was classified as a Red-Yellow Latosol, of medium texture, being collected in the depth of 0.00 to 0.30 m, disruptioned, passed in a sieve of 4 millimeter and homogenized. Soil samples were sent to the CCAE/UFES Soil Laboratory for chemical and physical characterization (Table 1), according to the methodology proposed by EMBRAPA [28].

The soil acidity correction was performed according to the methodology proposed by Prezotti et al. [29], the nutritional fertilization as recommended by Novais, Neves and Barros [30] and the soil water retention curve according to Van Genuchten [31].

The seedlings of arabica coffee plants were obtained in a suitable and certified nursery, available in tubes with commercial substrate, free of pathogens, and presented a pattern of three pairs of leaves. During the experiment, the monitoring and management of pests and diseases were carried out.

The performance of the plants submitted to the water deficit was followed by the method of the fraction of transpirable soil water (FTSW) in two stages of water deficit, as described by Sinclair & Ludlow [18]; in stage I, water is freely available in the soil, with no water deficit, where stomatal conductance and transpiration are at maximum rate; in stage II, the available water in the soil decreases, and the stomatal conductance and the transpiration decrease, to maintain the water balance and the cellular turgescence.

The initial weight of each plot (Wi) was determined, which corresponds to its weight with the soil moisture near the field capacity, through the weighing of the pots already with the seedlings established after being saturated and remain for 48 hours in free drainage. The soil surface of each pot was covered with white styrofoam to ensure that all lost water was obtained from the transpiration process.

The applications of the water regimes were initiated according to the age of the plants

Table 1. Chemical and physical attributes of the Red-Yellow Latosol used as substrate

pH	P	K	Ca	Mg	BS	CEC	V	Sand	Silt	Clay
	mg dm^{-3}			cmol$_c$ dm^{-3}	%				%	
4.51	2.50	30.0	0.41	0.26	0.80	4.60	17.23	66.0	6.0	29.0

Extraction and determination: pH in water (1:2.5); P, K, Na: Mehlich 1; Ca, Mg, Al: KCl (1M); H+Al: calcium acetate (0.5M), CTC a pH 7.0. For physical analysis slow stirring at 50 rotations per minute for 16 hours, with wagner type stirrer; chemical dispersant: NaOH 0.1 mol L^{-1} and determination of the silt and clay fractions by the pipette method [13]

(P1 = 45, P2 = 75 and P3 = 105 days after planting), applying the water deficit in the Td pots, which were no longer irrigated until end of the experiment, that is until the relative transpiration (RT) of the Td plants reached 10% of the transpiration of the T0 plants, which occurred before the plants reached the permanent wilting point.

All experimental plots were weighed daily at 5:00 p.m. in an electronic weighing-machine with a capacity of 25 kg and variation of 0.5 g, thus, knowing the amount of water that the T0 treatment plants transpired from the previous day. The daily loss of water by the T0 plants was determined according to equation 1 and for Td according to equation 2, as shown by Kelling et al. [25]:

$$RT_0 = W_i - W_d \tag{1}$$

where: WDL_0 – water daily loss of T0 plants; W_i – weight of the each pot on the day of the start of the experiment; and W_d – weight of same pot on the day of weighing;

$$RT_d = W_{da} - W_d \tag{2}$$

where: WDL_d – water daily loss of Td plants; W_{da} – weight of the each pot on the previous day; and W_d – weight of same pot on the day of weighing.

Then, the average daily loss of water in the 8 plants constituting the T0 treatment in each experiment was calculated. With the obtained value the water lost was returned, each pot returning to its value of Wi. The Td plants did not undergo water replacement in order to reach the pre-established limit.

With these variables, it was possible to monitor the decrease of RT by the equation 3, using the daily values of the relative transpiration of the plants under Td treatment (DTT_d) and the average daily value of the relative transpiration of the T0 treatment plants (ADT_0), as described by Sinclair & Ludlow [18]. The 10% limit of relative transpiration was adopted because it is assumed that below this transpiration rate the stomata are closed and the loss of water is due only to epidermal conductance.

$$RT = \frac{DTT_d}{ADT_0} * 100 \tag{3}$$

where: RT – relative transpiration; DTT_d – daily transpiration of treatments that suffer deficit; and ADT_0 – average daily transpiration of treatment T0.

The end of the water deficit period was determined when the Td treatment plots reached 10% of the relative transpiration of the T0 treatment, at which time the weight of each plot was calculated and it was determined as final weight (Wf).

In order to evaluate coffee responses to water deficit we used the concept of fraction of transpirable soil water (FTSW), used by several authors such as Sinclair and Ludlow [18], Muchow and Sinclair [32], Bindi et al. [33], Lago, et al. [34], Rodrigues et al. [27] Kelling et al. [25] and Pizetta et al. [35]. The fraction of transpirable soil water was calculated by equation 4 [18].

$$FTSW = \frac{(W_{daily} - W_f)}{(W_i - W_f)} \tag{4}$$

where: FTSW – fraction of transpirable soil water; W_{daily} – weight of the experimental plot in each day; W_i – initial weight of each experimental plot; and W_f – Final weight of each experimental plot.

The growth variables evaluated were: plant height (PH, in centimeter, length of main stem at ground level to apical bud) and leaf area (LA, centimeter squared), calculated by the sum of the leaf area of all individual leaves of the plant. The growth analysis were performed every 3 days, biometrically with the help of a graduated ruler.

Based on daily total LA and daily PH data, daily leaf area (LA) and daily height (PH) were calculated for each clone, considering the first normalization with the objective of normalizing the data in the range of 0 and 1, according to Equation 5 [25].

$$V = \frac{Vd_{total}}{V0_{total}} \tag{5}$$

where: V – variable in study (LA; PH); Vd_{total} – increase of the total variable in each Td plant; and $V0_{total}$ – Increase of the total variable in each T0 plant.

The second normalization was carried out with the intention of reducing the variations between plants, caused by the environmental conditions of the greenhouse, according to equation 6, which was based on principles described by

Sinclair et al. [36] and has already been used in other works such as Rodrigues et al. [27], Pizetta et al. [35] and Martins et al. [37]:

$$Nv = \frac{value\ RT\,10\% - value(n)}{value\ RT\,10\% - v_{initial}} \tag{6}$$

where: Nv – normalized variable; Value RT 10 % – final value of the variable (when RT was 10%); Value (n) – value of the variable on the specific day; and $V_{initial}$ – value of the variable on the first day of the experiment.

The growth data of the dependent variables obtained from the second normalization were adjusted to a logistic function of the FTSW independent variable in a non-linear sigmoidal model (Equation 7) [33].

$$y = \frac{1}{(1 + \exp(a.(X - b)))} \tag{7}$$

where: y – dependent variable (height and leaf area of plants); X – fraction of transpirable soil water; and a and b – coefficients estimated using non-linear regression procedures.

The adjusted curves were used to determine the critical FTSW value at which relative transpiration reduction was initiated. After the Td plots reached the pre-established limit, four plants were cut from each treatment, the remaining pots were saturated with water in order to return the soil moisture to the field capacity. During a period of 30 days periodic irrigations were carried out in order to provide adequate conditions to be able to quantify the effect of the water deficit between plants and their potential recovery capacity.

The data were submitted to analysis of variance (P=0.05), when the F test was significant, the Tukey test (P=0.05) was used for the qualitative factor and regression analysis for the factors quantitative. The models were chosen based on the significance of the regression coefficients, using the student's t test, at the 5% probability level and by the determination coefficient, using SAEG Software, version 9.1.

3. RESULTS AND DISCUSSION

Table 2 shows the responses of the relative transpiration and growth variables as a function of the treatments in the three periods. It is observed for all variables in the three periods, the water deficit influenced negatively, where the capacity of recovery of the plants varied according to the period. Therefore, P3 was statistically superior to the other periods for all

Table 2. Averages of the variables relative transpiration, plant height and leaf area, evaluated at the beginning, at the end of the experiment and after the recovery period, when submitted to treatments T0 (without water deficit - control) and Td (with water deficit), in the three periods of days after planting (P1 - water deficit applied 45 days after planting, P2 - water deficit applied 75 days after planting and P3 water deficit applied 105 days after planting)

P	Initial		$\bar{x}$	Final		$\bar{x}$	Recovery		$\bar{x}$
	T_0	T_d		T_0	T_d		T_0	T_d	
				Relative Transpiration					
3	106.2	110.3	108.2 a	106.6	6.1	56.3 a	116.3	90.8	103.5 a
2	100.3	111.9	106.0 a	99.9	9.3	54.6 a	100.0	82.3	91.1 b
1	106.9	101.7	104.2 a	105.7	12.3	59.0 a	100.0	71.1	85.5 b
$\bar{x}$	104.4 a	107.9 a		104.0 a	9.2 b		105.4 a	81.4 b	
CV	7.47(%)			12.98(%)			5.48(%)		
				Plant Height (cm)					
3	52.5	51.6	52.0 a	59.3 Aa	55.5 Ab	114.9	66.9	63.2	65.0 a
2	36.7	34.3	35.5 b	50.9 Ba	46.5 Bb	97.4	60.0	56.6	58.3 b
1	24.5	24.6	24.5 c	38.1 Ca	28.0 Cb	66.2	43.2	35.6	39.3 c
$\bar{x}$	37.89 a	36.84 a		148.4	130.1		56.675a	51.7b	
CV	3.66(%)			4.38(%)			5.35(%)		
				Leaf Area (cm²)					
3	1672.4 Aa	1715.0 Aa	1693.7	2015.8 Aa	1942.5 Aa	1979.2	2406.1	2300.9	2353.4 a
2	1102.7 Ba	901.4 Bb	1002.1	1268.2 Ba	953.2 Bb	1110.8	1993.3	1827.1	1910.1 b
1	527.3 Ca	458.0 Ca	492.7	731.0 Ca	412.3 Cb	571.7	1150.2	715.0	932.6 c
$\bar{x}$	1100.8	1024.8		1338.4	1102.7		1849.8 a	1614.3 b	
CV	8.37(%)			6.96(%)			8.62(%)		

**The averages followed by the same lowercase letter in the row and upper case in the column do not differ from each other at the 5% probability level by the Tukey test. CV = coefficient of variation, $\bar{x}$ = average* variables, followed by P2 and P1. Thus, it can be affirmed that the irreversibility of the effects of the water deficit is related to the plant stage of development [20].

In the initial evaluation there was no significant interaction between the levels of the variables except for LA, due to the difficulty of standardization of this one, although in the selection the maximum of homogeneity between plants was sought, a circumstance also reported by Kelling et al. [25].

For RT, the averages of the isolated factors were statistically the same, indicating that at the beginning of the experiment all the plants had maximum potential of transpiration. For PH and LA there was a difference between the time factor and plant age, and for LA there was also a difference between treatments in P2.

The end of the experiment occurred when the T_d plants reached 10% of the RT of the T_0 plants, thus, the averages of the periods levels were statistically equal and significant between the treatments, as expected, varying the number of days that each season led to reach the pre-established limit. In P1 the plants were in water deficit for 33 days, in P2 21 days and in P3 18 days. During the water replenishment period, the most developed plants were able to restore their growth more easily, reaching a mean of 90.04% (P3), 82.09% (P2) and 71.40% (P1) equivalent to the RT of the T_0 treatment (Fig. 1).

The difference found in the number of days is due to the stomatal closure [38] which is a common process in plants under water stress. This stomatal closure is a strategy developed by the plant in order to deal with the environmental adversity, which causes a reduction in RT avoiding the loss of turgidity of the cells [39], improving the recovery. The authors Costa et al. [40] working with deficit and recovery of *Myracrodruon urundeuva* alemão plants observed a rapid recovery in the rate of plants transpiration after going through water restriction period.

However, this strategy of stomatal regulation developed by the plants varies according to the different stages of development, which allowed the best performance of the arabica plants in the third period, being statistically superior to the other periods, with less compromise of the development of the plants and greater recovery capacity.

In the final evaluation for PH and LA, there is a significant interaction between the factors. The PH variable obtained better performance in P3 (Fig. 2), but statistically different among treatments (6.14% less than T0). This response directly affected the plots during the recovery period, where P3 obtained the highest mean, reducing the difference to 5.75% (Fig. 2).

The results corroborate with that found by authors as Peloso et al. [41] and Scalon et al. [42]. Therefore, Kramer e Boyer [43] explain that this reduction in growth may be due to the reduction in cell turgor, caused by the water deficit in the soil, directly affecting the process of cell elongation, which requires minimum levels of turgidity.

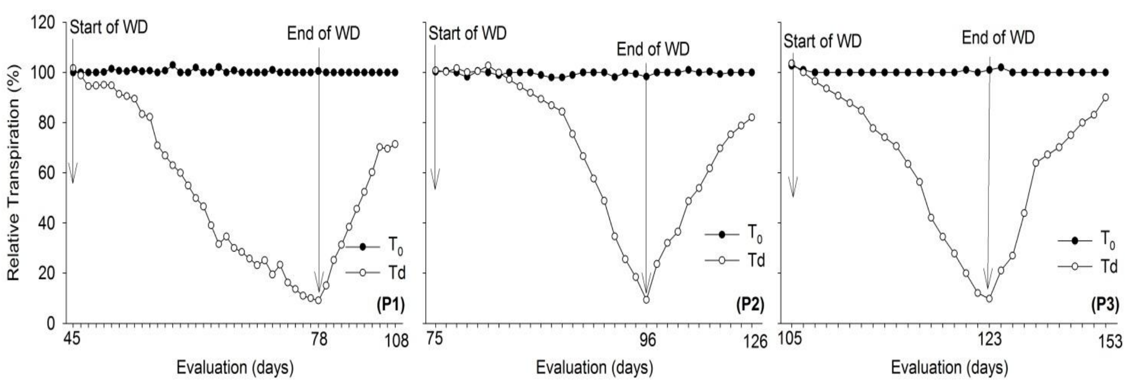

Fig. 1. Behavior of the relative transpiration variable (TR) of the arabica coffee, during the treatments, "P1," P2 "and" P3 "(45, 75 and 105 days after planting, respectively), and its recovery period. In that T_0 = irrigated plots throughout the experiment and T_d = water deficit induced to the plants reached 10% of the relative transpiration of T_0

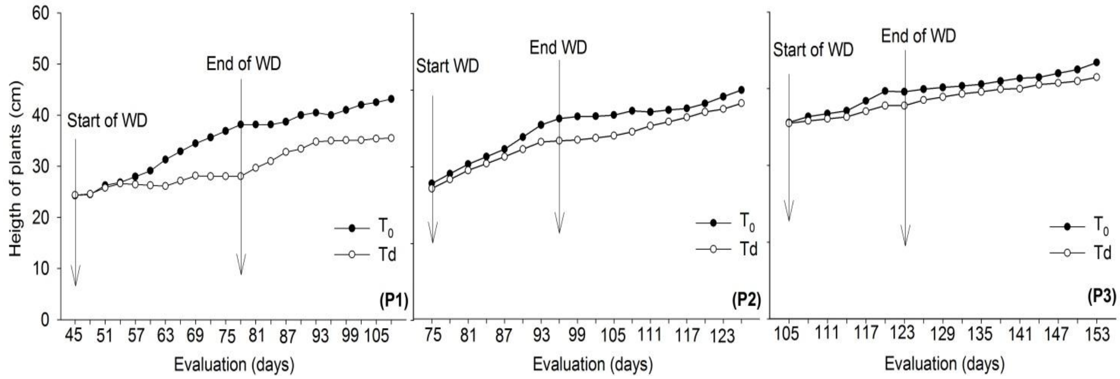

Fig. 2. Behavior of the plant height variable (PH) of the arabica coffee, during the treatments, "P1," P2 "and" P3 "(45, 75 and 105 days after planting, respectively), and its recovery period. In that T0 = irrigated plots throughout the experiment and Td = water deficit induced to the plants reached 10% of the relative transpiration of T_0

For the variable LA at the end of the experiment, there is significant interaction. Where the best results were obtained in P3, being statistically equal to the end of the water deficit period, presenting a smaller difference between the treatments and between the periods (9.74%). Thus, it allowed a better response of the recovery period, reducing the difference to 4.40% (Fig. 3), statistically different from the other periods. In P1 and P2 there was no difference between the means of T0 and Td.

This reduction of LA was also verified in studies with other plant species, such as peanut, sesame and castor bean [44], conilon coffee [45] and pitanga [46]. The authors Peloso et al. [41] verified the negative influence of the water unavailability in the leaf area of the plants, occurring reduction of this parameter with the decrease of the amount of water in the soil. Physiologically, the decrease of leaf area is the most effective response to water deficit, being a strategy of the plant to develop in environment with water restriction [9]. The leaf area reduction contributes to the decrease of relative transpiration and photosynthesis, thus decreasing growth for greater water saving in soil [47].

All the logistic equations, in the three periods of water deficit, presented good precision, with high values of efficiency of the statistical model (Esm) and low values of standard error of the estimate (Sde), corroborating with work of Araujo [21,22], Lago et al. [19,34], Martins et al. [37] and Rodrigues et al. [27].

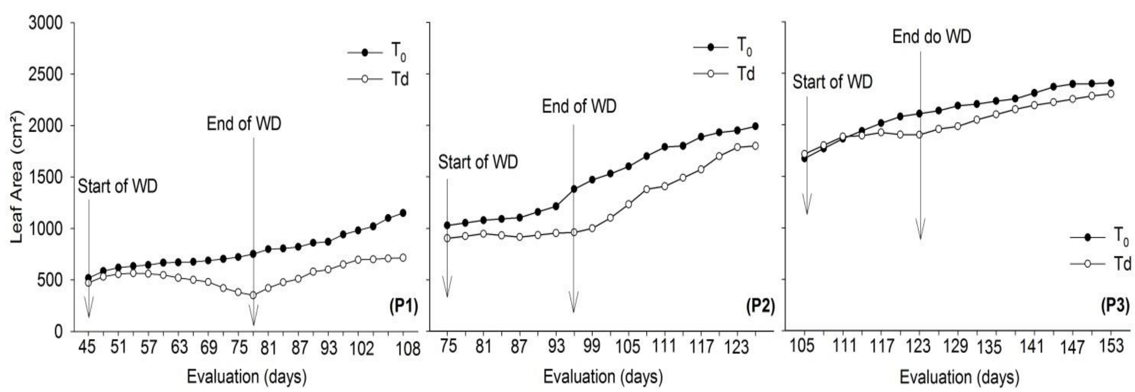

Fig. 3. Behavior of the leaf area variable (LA) of the arabica coffee, during the treatments, "P1," P2 "and" P3 "(45, 75 and 105 days after planting, respectively), and its recovery period. In that T_0 = irrigated plots throughout the experiment and T_d = water deficit induced to the plants reached 10% of the relative transpiration of T_0

The critical FTSW value in all variables decreased as a function of the greater age of the plants. The Arabica coffee tree presented a superior response to short-term water deficit in P3 and P2, with P1 being more sensitive to short-term water deficit, with early stomatal closure and loss of turgescence [25]. This fact was already expected, since the younger plants have a less developed root system [26], making soil exploration difficult.

The RT variable (Fig. 4) in P1 obtained a critical FTSW mean value of 0.76, in P2 of 0.67 and in P3 of 0.47. The values diverge from Pizetta et al. [35] who verified critical FTSW value of 0.52 and 0.44 for arabica coffee Catucaí Vermelho 785-15 variety water deficit applied at 30 and 90 days after planting respectively. Santos & Carlesso [20] argue that this result is common, since the effects of water deficiency may vary according to genotype, duration, severity and stage of development of the plant.

The high value of FTSW represents the precocity of stomatal closure, leading to reduced plant growth in a short cycle of deficit [9]. However, Ray and Sinclair [48] state that in cultivation systems, species that reduce the degree of stomates opening in higher FTSW will save water and increase their chances of survival in prolonged drought periods.

For the plant height variable (Fig. 5) it is observed a greater resistance to the deficit again as a function of the higher age of the plants, finding critical FTSW values of 0.81, 0.70 and 0.52 in P1, P2 and P3 respectively. In the work of Rodrigues et al. [27] critical FTSW value with the advancement of the evaluation times for PH were 0.67; 0.55; 0.36 at 30, 60 and 90 days after planting.

The variable PH obtained higher values of FTSW in relation to RT, indicating the greater sensitivity of this the water variation, and also, being the first variable to be affected. Corroborating with Larcher [6], where PH is the first and most sensitive variable to respond to the water deficit, causing a decrease in turgor pressure and consequently paralysis in the process of growth and extension of the plant.

For the variable LA (Fig. 6), critical FTSW values of 0.69, 0.5 and 0.43 were obtained for P1, P2 and P3 respectively. According to DaMatta; Ramalho, [47], the LA reduction is an adaptive strategy for plants to resist to long water restriction contributing to the reduction of transpiration, leading to lower growth, but ensuring water savings.

Similar result was verified by Pizetta, et al. [35], where FTSW values for LA were 0.97 at 30 days after planting of arabica coffee plants and from 0.47 to 90 days. Martins et al. [37] claim that a decrease in the turgidity of the cells before stomatal closure is enough to affect the metabolism and cause a reduction in the growth and development of the seedlings.

The critical FTSW values for LA are lower than the other variables. Indicating that the stoppage of leaf growth occurred after the stomatal closure mechanism, since there was no decrease in the cellular turgescence sufficient to reduce cell expansion and consequently the foliar growth

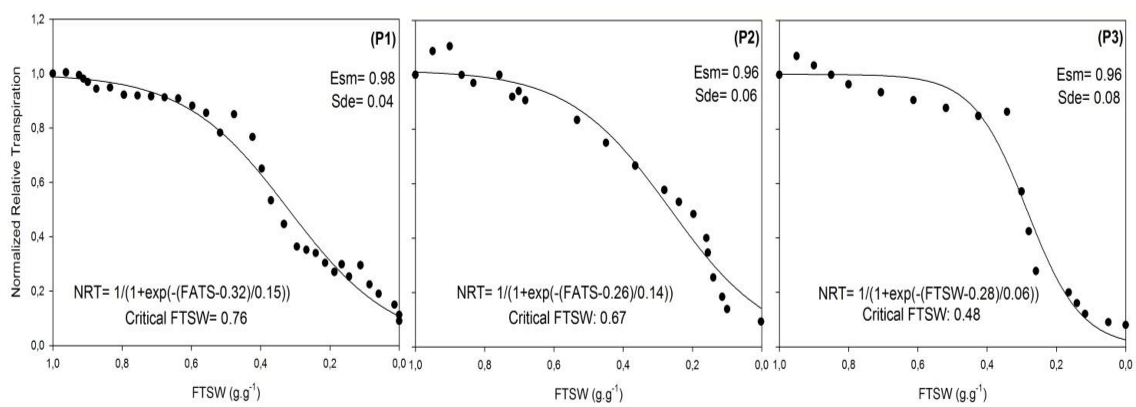

Fig. 4. Behavior of the normalized relative transpiration variable (NRT) of arabica coffee in function of the fraction of transpirable soil water (FTSW), in the three periods "P1", "P2" and "P3" (45, 75 and 105 days after planting). In that T0 = irrigated plots throughout the experiment and Td = water deficit induced until the plants reach 10% of the relative transpiration of T0

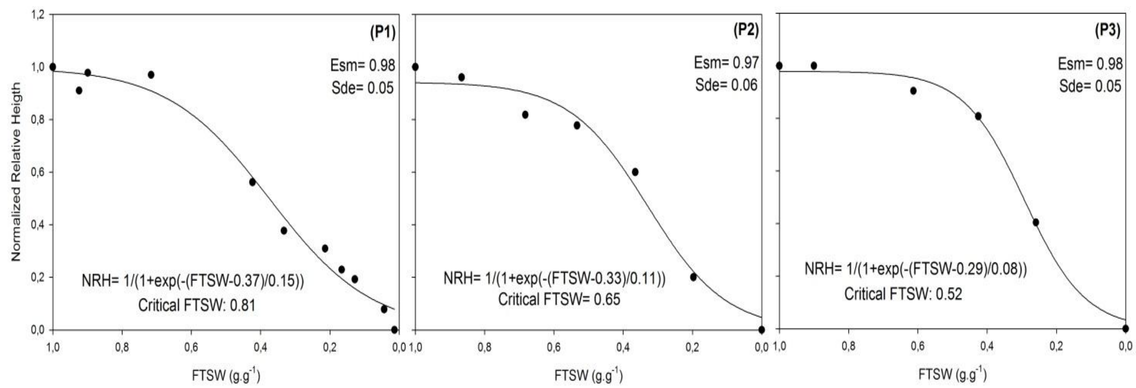

Fig. 5. Behavior of the normalized relative height (NRH) of arabica coffee in function of the fraction of transpirable soil water (FTSW), in the three periods "P1", "P2" and "P3" (45, 75 and 105 days after planting). In that T0 = irrigated plots throughout the experiment and Td = water deficit induced until the plants reach 10% of the relative transpiration of T0

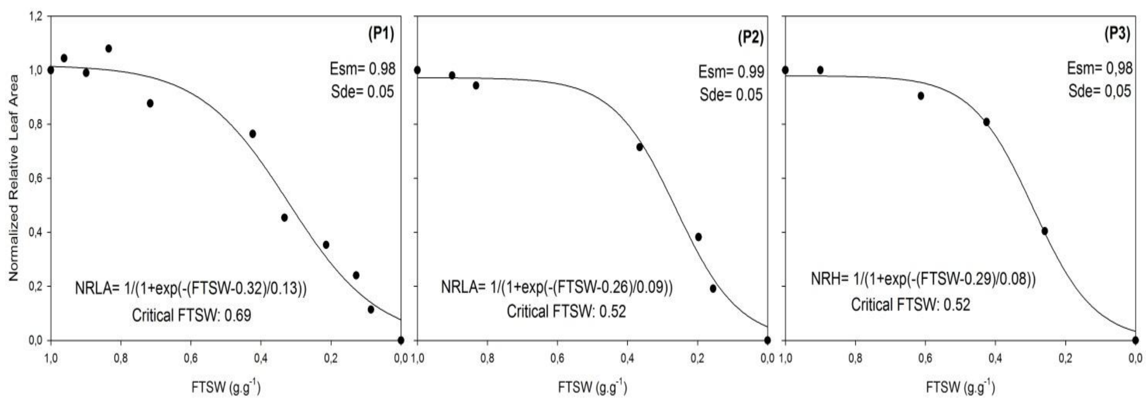

Fig. 6. Behavior of the normalized relative leaf area (NRLA) of arabica coffee in function of the fraction of transpirable soil water (FTSW), in the three periods "P1", "P2" and "P3" (45, 75 and 105 days after planting). In that T0 = irrigated plots throughout the experiment and Td = water deficit induced until the plants reach 10% of the relative transpiration of T0

[49]. According to Lago et al. [19], this result indicates that the plants may have an efficient stomatal control mechanism, since they can reduce water consumption due to the reduced stomatal opening, delaying the effect of reduction on leaf growth and senescence.

4. CONCLUSIONS

The plant height variable was the first and most sensitive to soil water deficit.

It is verified that the more developed plants (P3) were more efficient in the stomatal control, and consequently more resistant to the water deficit.

For the quantitative variables, it were obtained the critical FTSW values of relative transpiration in P1 (0.76), P2 (0.67), P1(0.48); plants height in P1 (0.81), P2 (0.64) e P3(0.52) and for leaf area in P1 (0.69), P2 (0.52) e P3(0.43).

The plants later submitted to stress (P3) presented better response of the variables during 30 days of recovery imposed.

The water deficit directly affected the growth and transpiration of the plants, with lower effects on P3 plants, allowing Td plants to have averages statistically equal to plants T0 for leaf area variable.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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