FLOWERING AND LEAF WATER POTENTIAL IN COFFEE UNDER DIFFERENT WATER REGIMES AND PLANTING DENSITIES

Dalyse Toledo Castanheira[1], Myriane Stella Scalco[2], Iraci Fidelis[3], Gleice Aparecida Assis[4], Fábio Santos Pereira[5]

(Recebido: 2 de janeiro de 2012; aceito: 4 de julho de 2012)

ABSTRACT: The study of water relations in coffee is of utmost importance at all stages of crop development. The aim of this study was to evaluate "pre-dawn" leaf water potential and the total average production of flowers in non-irrigated and irrigated coffee plants under different water regimes in four planting densities over a two-year period. The cultivar Rubi MG-1192 was used, planted in January 2001 in a randomized block experimental design in split-plots with three replications. Treatments consisted of three water regimes: (i) irrigation when soil water tension reached values around 20 kPa and suspension of irrigation during July and August; (ii) irrigation when soil water tension reached values around 60 kPa and suspension of irrigation during July and August and (iii) a non-irrigated control. Four planting densities were used: (i) 2500 (4.0 x 1.0 m), (ii) 3333 (3.0 x 1.0 m), (iii) 5000 (2.0 x 1.0 m) and (iv) 10000 plants ha-1 (2.0 x 0.5 m). The "pre-dawn" leaf water potential (Yf) was determined using a pressure chamber. In 2009, the lowest values observed were -1.6 MPa in non-irrigated and irrigated coffee at 60 kPa at a density of 2500 plants ha-1. These values were observed during September, October and November. In the second year, the value of -1.5 MPa was reached at the end of the period of suspension of irrigation (August) and occurred in less dense plantings. In both years, in dense coffee plantings, the water regime did not affect total average production of flowers. The values of leaf water potential did not correlate with the total average production of flowers.

Index terms: Water stress, coffee, irrigation, spacing.

FLORAÇÃO E POTENCIAL HÍDRICO FOLIAR DE CAFEEIROS SOB DIFERENTES REGIMES HÍDRICOS E DENSIDADES DE PLANTIO

RESUMO: *O estudo das relações hídricas do cafeeiro é de suma importância em todas as fases de desenvolvimento da cultura. Objetivou-se ,neste trabalho,avaliar, ao longo de dois anos, o potencial hídrico foliar na "antemanhã" e a produção média total de flores de cafeeiros não irrigados e irrigados sob diferentes regimes hídricos, em quatro densidades de plantio. Foi usada a cultivar Rubi MG-1192, plantada em janeiro de 2001, no delineamento experimental de blocos casualizados, em esquema de parcelas subdivididas com três repetições. Os tratamentos constaram de três regimes hídricos: (i) irrigação quando a tensão da água no solo atingiu valores próximos a 20 kPa e suspensão das irrigações nos meses de julho e agosto; (ii) irrigação quando a tensão da água no solo atingiu valores próximos a 60 kPa e suspensão das irrigações nos meses de julho e agosto (iii) uma testemunha não irrigada e quatro densidades de plantio de: (i) 2500 (4,0 x 1,0m), (ii) 3333 (3,0 x 1,0m); (iii) 5000 (2,0 x 1,0m) e (iv) 10000 plantas* ha^{-1} *(2,0 x 0,5m). O potencial hídrico foliar (Yf) "antemanhã" foi determinado utilizando-se uma câmara de pressão. Em 2009, os menores valores observados foram de -1,6 MPa em cafeeiros não irrigados e irrigados a 60 kPa na densidade de 2500 plantas* ha^{-1}*. Esses valores foram observados nos meses de setembro, outubro e novembro. No segundo ano, o valor de -1,5 MPa foi alcançado ao final do período de suspensão de irrigação (agosto) e ocorreu em plantios menos adensados. Em ambos os anos, em cafeeiros adensados o regime hídrico não afetou a produção média total de flores. Os valores de potencial hídrico foliar não se correlacionaram com a produção média total de flores.*

Termos para indexação: *Estresse hídrico, café, irrigação, espaçamento.*

1 INTRODUCTION

Coffee culture in Brazil stands out as one of the most important agricultural activities, with great influence on the economy and socio-economic aspects of the country. Brazil is the main producer and exporter of coffee and second largest consumer, behind the United States in consumption.

The expansion of coffee cultivation to areas where the water deficit and the uneven distribution of rains are limiting factors to production, led to the necessity of the use of new technologies, such as irrigation. This technique also began to be used in areas considered suitable to water conditions, by offering the guarantee production in years of low rainfall or when there are periods of moisture stress in the phases of greatest need for crop water (SILVA; TEODORO; MELO, 2008).

The coffee yield is strongly influenced by the adequate supply of water and nutrients (COELHO et al., 2009). Thus, the study of the water status of the crop is essential to the understanding of the

[1,2,4]Universidade Federal de Lavras/UFLA - Departamento de Agricultura/DAG - Setor de Cafeicultura/CEPECAFE Cx. P. 3037 - 37.200-000 - Lavras-MG - dalysecastanheira@yahoo.com.br, msscalco@dag.ufla.br, gleice_ufla@yahoo.com.br
[3]Instituto Federal de Educação, Ciência e Tecnologia de Roraima - Campus Amajari -elifidel@yahoo.com.br
[5]Universidade Federal de Lavras/UFLA - Lavras-MG - fa29binho@hotmail.com

productive potential of the coffee, because this factor can directly affect productivity (MATTA, 2004). The understanding of the relationships between water and coffee can provide subsidies to farmers and researchers for making more informed decisions about the overall management of the crop (RENA; MAESTRI, 2000).

Thus, the leaf water potential stands out as an important parameter in assessing the response of plant species to water stress (MORGAN, 1991; NOGUEIRA et al., 2001). Besides representing a quantification of the effect of water stress on the plant, the determination of leaf water potential of coffee, during the "predawn", independent of weather conditions, is closely related water reserves in the soil and can be a reference the need for irrigation (RENA; MAESTRI, 2000). However, in regions that do not normally have water restrictions and other climatic conditions for the cultivation of coffee, little information exists as to the applicability of this measure to determine the leaf water status of the coffee. Several authors have used the leaf water potential to quantify the period of water stress which induces a more uniform flowering and coffee, according to Guerra et al. (2007), is in the range of -2.0 MPa. With synchronization of flowering in addition to the increased uniformity of maturation, the productivity must be maintained at a level higher. Conversely, values below -2.5 to -2.8 MPa can significantly reduce the number of coffee flowers (SILVA et al., 2009).

There are controversies regarding the values of leaf water potential found for different regions and can induce dormancy of buds of coffee. Under natural conditions, the bloom occurs after the first rains (NASCIMENTO; OLIVEIRA; SILVA, 2010). In irrigated crops, Crisosto, Grantz and Meinzer (1992) demonstrated that values less than -0.8 MPa, and subsequent irrigation stimulated buds. However, in the Zona da Mata of Minas Gerais, Soares et al. (2005) found that values of -0.8 MPa, -1.2 MPa and -1.9 MPa after 30, 60 and 90 days were not enough to induce dormancy of buds. In the southern region of Minas Gerais, Rezende, Faria and Lismar (2009), three-year evaluation concluded that the leaf water potential did not reach values that provide the concentration and uniformity of flowering coffee trees. In all cases mentioned above, the authors refer to the leaf water potential measured at the "before dawn."

The objective of this study was to evaluate leaf water potential in the "predawn" and average total production of coffee flowers unirrigated and irrigated under different water regimes in four planting densities in Lavras - MG over two years.

2 MATERIALS AND METHODS

The experiment took place in an area located in the experimental field of the Setor de Cafeicultura do Departamento de Agricultura da Universidade Federal de Lavras, in Lavras, MG. The geographic coordinates of the city are 21 º 14'06" south latitude and 45 º 00'00" west longitude, at an average altitude of 910 m. The climate is classified as Cwa according to Köppen (mesothermal with mild summers and mild and dry winter). Cultivar of Coffea arabica L. used was Rubi - MG 1192. Planting took place in January 2001 in soil classified as Latic Ferralsol. In August 2007, after the harvest, proceeded to pruning neck and crop. The pruning was carried out at 0.40 m from the orthotropic branch and neckline, and 1.40 m from ground level.

The experimental design was randomized blocks in a split-plot with three replications. The treatments consisted of three water regimes: (i) irrigation when soil water tension reached values close to 20 kPa and suspension of irrigation in the months of July and August, (ii) irrigation when soil water tension reached values close 60 kPa and suspension of irrigation in the months of July and August (iii) a witness not irrigated and four densities of: (i) 2500 (4,0 x 1,0 m), (ii) 3333 (3.0 x 1.0 m) (iii) 5000 (2.0 x 1.0 m) and (iv) 10000 plants ha-1 (2.0 x 0.5 m). Each subplot consisted of 10 plants considered useful the eight central plants. In the top and bottom edges of each plot (planting density) was used as a row of plants surround. The experimental area consisted of 288 useful plants.

The irrigation system consisted of a central control unit (pumping system, sand filters and screen, fertilizer injector, pressure gauges and connections), the main line of PVC pipes, PN 80, drop lines, PVC lateral lines with flexible polyethylene drip self-compensating (flow rate of 3.78 L h-1) and records. Each sub-plot irrigation was controlled by means of registers installed in the bypass lines leading the water to the side lines of the three replicates per treatment.

Tensiometers puncture whose readings were taken by a digital tensiometer were installed at depths of 0.10, 0.25, 0.40 and 0.60 m, 0.10 m apart around the stem base of the plants. Voltage readings of soil water were performed daily in the morning. Irrigation of each subplot occurred when the voltage reading of the water in the soil at a depth of 0.25 m indicated strain relative to that irrigation treatment.

The tensiometers were placed in a repetition of each treatment representative of the experimental area. The measurements were made at each depth three times a week and / or treatments as necessary in reading the value of which was close to the voltage irrigation. The correspondence between water tension and soil moisture characteristic curve was obtained by soil moisture, which was previously determined in the laboratory.

Liming and fertilization were carried out according to soil and foliar analysis, being based on the recommendations for the use of lime and fertilizers in Minas Gerais (Guimarães et al., 1999), with a 30% increase in fertilizer, as recommended by santinato and Fernandes (2002) for irrigated coffee. The nutrients nitrogen (BUN livestock with 45% N) and potassium (potassium nitrate with 44% K2O) were applied by fertigation. The non-irrigated plots were fertilized conventionally. In both types of fertilization (conventional and fertigation), splitting was performed four times, from October to January. The foliar micronutrients were supplied, according to the levels observed in the nutritional analysis.

The leaf water potential (Yf) " predawn " was determined using a pressure chamber , model 1000- PMS Instrument Company . The determination constituted the sampling of active leaves , free of symptoms of diseases , nutritional deficiencies and pest attack , being held this morning at 5am , in three replicates of each treatment . The leaves were collected in the middle third plagiotropic higher plants , located on the fourth node from the apex of the branch (Silva et al . , 2008) . These were wrapped in aluminum foil , placed in plastic bags inside a Styrofoam and then evaluated in the chamber , applying pressure until occurrence oozing done by cutting the petiole of the leaf. The readings of leaf water potential were performed monthly . During July and August , in which irrigation was suspended , the readings were taken once a week . These treatments before starting the suspension irrigation was conducted to raise the soil moisture to field capacity .

By the end of the evaluation period , determinations were made of leaf water potential , which covered the period from May 2009 to May 2011 . Here are discussed the events throughout 2009 and 2010 since, in the five months of 2011 evaluation , the values of leaf water potential remained unchanged . Throughout the evaluation period , including periods of suspension of irrigation , soil moisture at 0-20 cm was monitored at the same times for the determination of leaf water potential " predawn " , gravimetric method. The three plants where measurements were made of leaf water potential , it was twice a week (Monday and Friday) , or even more frequently , the occurrence of flowers opening in a couple of branches of each plant functional . It is necessary to emphasize that small blooms occurred in July and August , periods often coincide with the harvest period , have not been evaluated . Were considered those flowers open from buds that reached anthesis (OLIVEIRA , 2003) , and to avoid recounts , the flowers had already counted the tip of its petals dotted with a small scissors (OLIVEIRA , 2002) . The count was made of flowers covering the first flowering (September) until flowering when there were still significant (November-December) . For analysis of Variance flowering was considered the sum of the number of flowers open from the beginning until the end of the evaluation period and the averages were compared by grouping averages Scott -Knott at 5 % probability .

3 RESULTS AND DISCUSSION

In 2009, the leaf water potential (Ψf) reached lower values (minimum value of -1.6 MPa) during the months of September, October and November, indicating a possible effect of water stress on the plant (Figures 1 a, b, c, d). These values were higher in initial spacing and coffee not irrigated or irrigated when the soil water tension reached values close to 60 kPa.

In these months (September to November), although the rainfall exceeded the average of 100 mm, the maximum temperatures (29.3 Co), medium (21.8 Co) and minimum (16.8 Co) slightly larger in this period, the reduction in average relative humidity of 77.6% and an average radiation of 267 W m-2 may have influenced the process that evaporation was 4.4 mm (Table 1). According to Matta and Rena (2002), the stomata of trees are highly sensitive to reduced relative humidity.

In comparison to the other months of the year, the average evapotranspiration of the crop in the months of September, October and November (4.4 mm) was above the average of 12 months (3.3 mm). Thus, there was a strong relationship between water demand in these months and values of leaf water potential in coffee under more open spacing.

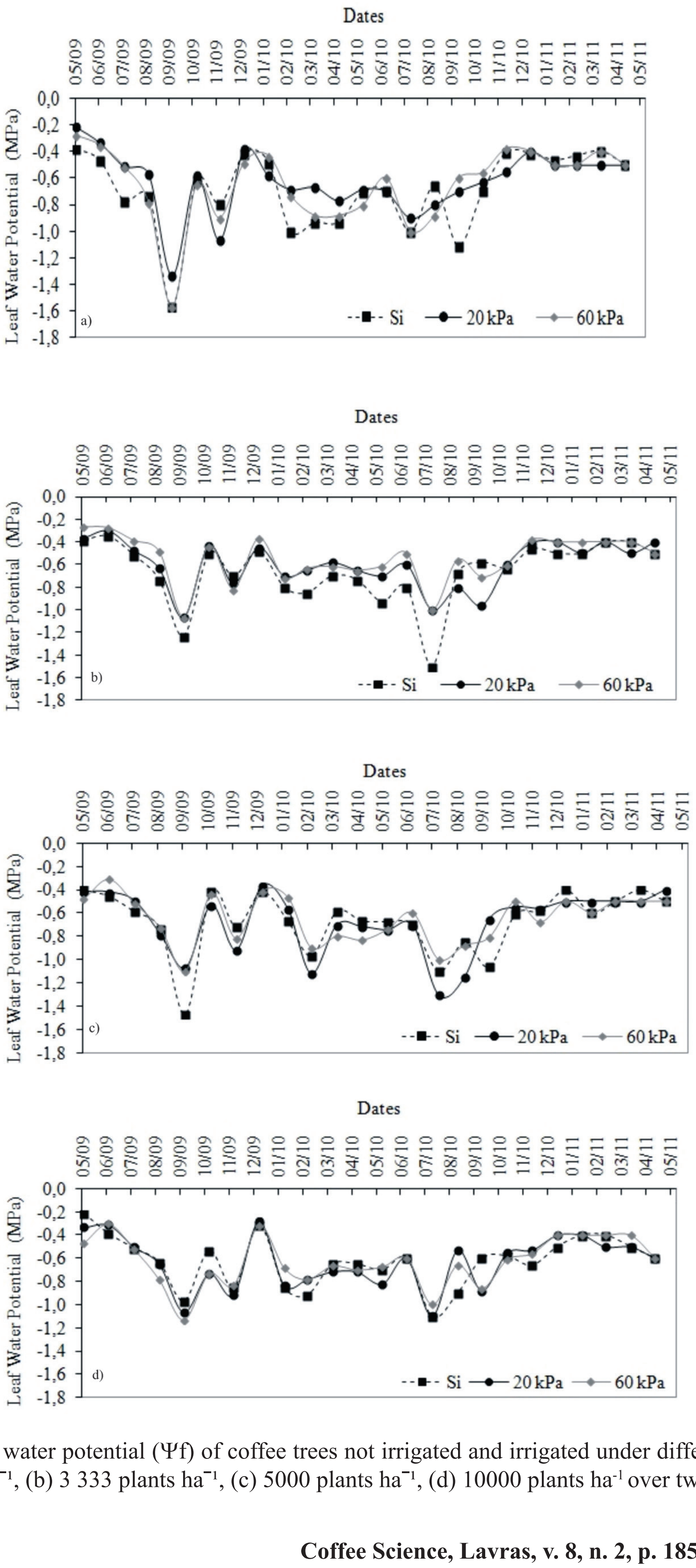

FIGURE 1- Leaf water potential (Ψf) of coffee trees not irrigated and irrigated under different hidric regimes at (a) 2500 plants ha^{-1}, (b) 3 333 plants ha^{-1}, (c) 5000 plants ha^{-1}, (d) 10000 plants ha^{-1} over two years.

TABLE 1 - Weather variables for the assessment period of leaf water potential (2009 and 2010).

Months	*2009*							*2010*						
	T max *Cº*	*T ave* *Cº*	*T min* *Cº*	*P* *mm*	*UR* *%*	*Rad* *W/m²*	*ETo* *mm*	*T max* *Cº*	*T. ave* *Cº*	*T. min* *Cº*	*P* *mm*	*UR* *%*	*Rad* *W/m²*	*ETo* *mm*
Jan	28.1	21.9	18.1	331.7	83.4	187	3,3	32,4	23,0	16,1	130,6	79	229	4,1
Feb	29.2	22.6	18.3	186.6	82.3	218	3,9	33,2	23,1	16,3	92,8	76	198	3,6
Mar	28.2	22.3	18.5	197.5	84.3	181	3,3	31,3	22,2	15,2	72,4	82	170	3,1
Apr	25.3	19.4	15.4	143.3	92.2	175	2,6	30,6	20,3	9,5	67	78	147	2,4
May	24.1	17.8	13.7	22.8	89.2	137	1,8	29,5	17,9	6,5	15	78	128	1,8
Jun	23.1	15.9	11.1	26.2	82.6	130	1,6	28,6	15,8	5,4	7,6	75	126	1,6
Jul	26.2	18.5	13.3	13.6	71.9	154	2,4	28,6	17,5	7,1	19,4	74	123	1,7
Aug	26.3	18.5	13.1	41.9	66.2	162	2,8	30,6	17,9	5,0	1,6	60	153	2,4
Sep	28.0	21.1	15.8	137.3	74.1	239	3,7	33,3	19,9	9,5	51,8	67	142	2,6
Oct	28.4	21.1	16.5	135.2	80.7	257	4,2	32,1	20,3	10,2	138,8	77	135	2,6
Nov	31.6	23.3	18.1	122.0	78.0	305	5,2	33,3	20,7	13,4	334	83	128	2,4
Dec	27.1	21.5	18.0	453.4	87.1	211	3,6	32,7	22,7	17,1	318	83	142	2,7
Average	27,0	20,3	15,8	151,0	80,8	196,4	3,2	31,3	20,1	10,9	104,0	75,7	155,7	2,6

TABLE 2 - Blades (mm) of water applied in different water regimes and planting density over two years (2009 and 2010).

Months	*2009 – 20 kPa with rest*				*2009 – 60 kPa with rest*			
	2500	*3333*	*5000*	*10000*	*2500*	*3333*	*5000*	*10000*
Jan	7,1	10,7	14,9	24,1	10,6	0,0	0,0	0,0
Feb	6,8	9,6	13,0	14,4	0,0	0,0	0,0	0,0
Mar	20,0	21,3	50,9	62,8	8,6	12,3	0,0	19,8
Apr	17,9	24,5	28,9	34,8	9,1	12,0	18,6	19,3
May	36,5	42,6	49,6	64,0	34,9	24,5	37,9	19,6
Jun	34,7	43,4	52,6	78,4	26,4	25,2	37,6	38,4
Sep	33,8	25,5	35,8	44,8	12,7	10,4	34,8	32,3
Oct	28,2	19,4	25,0	50,3	25,1	12,2	37,1	0,0
Nov	48,4	24,5	52,4	65,4	13,7	12,6	55,3	37,2
Dec	6,5	0,0	0,0	10,1	0,0	0,0	0,0	0,0
Total	239,9	221,5	323,1	449,1	141,1	109,2	221,3	166,6
Jul/Aug.	110,4	69,4	113,2	160,5	51,5	36,3	127,2	69,5
Month	*2010 – 20 kPa with rest*				*2010 – 60 kPa with rest*			
	2500	*3333*	*2500*	*3333*	*2500*	*3333*	*2500*	*3333*
Jan	11,7	0,0	11,7	0,0	11,7	0,0	11,7	0,0
Feb	35,3	23,6	35,3	23,6	35,3	23,6	35,3	23,6
Mar	31,7	25,4	31,7	25,4	31,7	25,4	31,7	25,4
Apr	28,9	27,7	28,9	27,7	28,9	27,7	28,9	27,7
May	53,1	45,7	53,1	45,7	53,1	45,7	53,1	45,7
Jun	43,8	45,1	43,8	45,1	43,8	45,1	43,8	45,1
Sep	51,2	31,6	51,2	31,6	51,2	31,6	51,2	31,6
Oct	49,8	22,8	49,8	22,8	49,8	22,8	49,8	22,8
Nov	13,4	0,0	13,4	0,0	13,4	0,0	13,4	0,0
Dec	25,2	25,5	25,2	25,5	25,2	25,5	25,2	25,5
Total	344,1	247,4	344,1	247,4	344,1	247,4	344,1	247,4
Jul/Aug	114,4	54,4	114,4	54,4	114,4	54,4	114,4	54,4

It is noteworthy that, even in smaller proportions, plants irrigated at 20 kPa tension irrigations with more frequent and larger water depths (Table 2) had lower leaf water potentials in these months. It is possible to infer that in this case, the climatological variables had the greatest influence on the fall of the leaf water potential in relation to the availability of soil water.

In 2010 , although there were lower values of leaf water potential (Yf) in the months of September, October and November , on average these values did not exceed -1.0 MPa (Figures 1a , 1b , 1c and 1d) . These values Yf were higher compared to those in the previous year in the same period (September , October and November). Climatological variables for this period in 2010 (Table 1) , compared to the same period last year (2009) indicated higher average maximum temperatures (32.0 ° C) , higher average rainfall (174.8 mm), however, smaller average temperatures (20.3 ° C) , lower minimum temperature (11.0 º C) , relative humidity (75.7 %), radiation (135 W m2) and reference evapotranspiration (2.5 mm) . Probably the heaviest rainfall occurred in 2010 contributed to the adequate supply of water to the plants and get higher leaf water potential , compared to the same period in 2009 . The leaf water potential of plants not irrigated and less dense soil was lower compared to plants irrigated and cultivated under conditions of crowding .

In 2009, in the months of July and August in which irrigation was suspended, the average leaf water potential reached a minimum value of -1.0 MPa in all planting densities and water regimes, except in the density of 2500 plants ha-1, where the leaf water potential (Yf) of unirrigated coffee reached values of -1.4 MPa (Figure 2 a, b, c and d). In these months, there were lower rates of evapotranspiration (Table 1). Consequently, the suspension of irrigation in the period may not have affected the values of leaf water potential. Coffee denser (5000 and 10000 plants ha-1) had higher leaf water potentials.

In 2010, during the period of suspension of irrigation (July and August) leaf water potential was becoming smaller and reached values of up to -1.6 MPa, the end of the suspension period (Figure 3 a, b, c and d .) The observed behavior relates - both the irrigated and non-irrigated coffee.

Considering month suspension in 2009 and 2010, it was observed that in the latter, the average rainfall for the months of July and August (21 mm) was almost half the precipitation occurred during the same period in 2009 (55.0 mm) . Lowest rainfall coupled with higher temperatures may explain the lower values of leaf water potential found in 2010.

In all evaluation periods, the soil remained wetter in denser spacing, corresponding to densities of 5000 and 10,000 plants ha-1, resulting in higher leaf water potential (Figures 2 and 3) due to the formation of a microclimate wet the crop (Table 3). Furthermore, in 2009, in the months of suspension of irrigation, soil showed higher moisture (average 0275 cm-3 cm-3) compared to the same period in 2010 (average of 0250 cm-3 cm-3), which resulted in lower leaf water potential sensed that year. There seems to be a combination of different climate variables, soil water availability and crop characteristics providing environmental conditions conducive to changes in leaf water potential in coffee.

Although there was a response of leaf water potential (Yf) over the total period of evaluation, it is noteworthy that: Maximum values are below the value to -2.0 MPa checked by Guerra et al. (2007) and recommended to provide a water stress on coffee as a way to synchronize flowering in the savanna region. As for Silva et al. (2009) commented that, sixty-day suspension of irrigation in July and August favored the production of water deficits on the order of -1.1 in Adamantina, -1,6 MPa in Mococa and –1,2 MPa in Campinas, which were more effective in flowering synchronization of uniformity with combining coffee production. According to the authors, the largest number of flowers and a low yield uniformity of plants irrigated continuously confirm the need for a dry period for flowering synchronization. They also comment that the low values of leaf water potential (-2.5 to -2.8 MPa) of non-irrigated plants significantly reduced the number of flowers compared to plants irrigated with reflections in the final production, indicating the need irrigation to ensure good flower initiation.

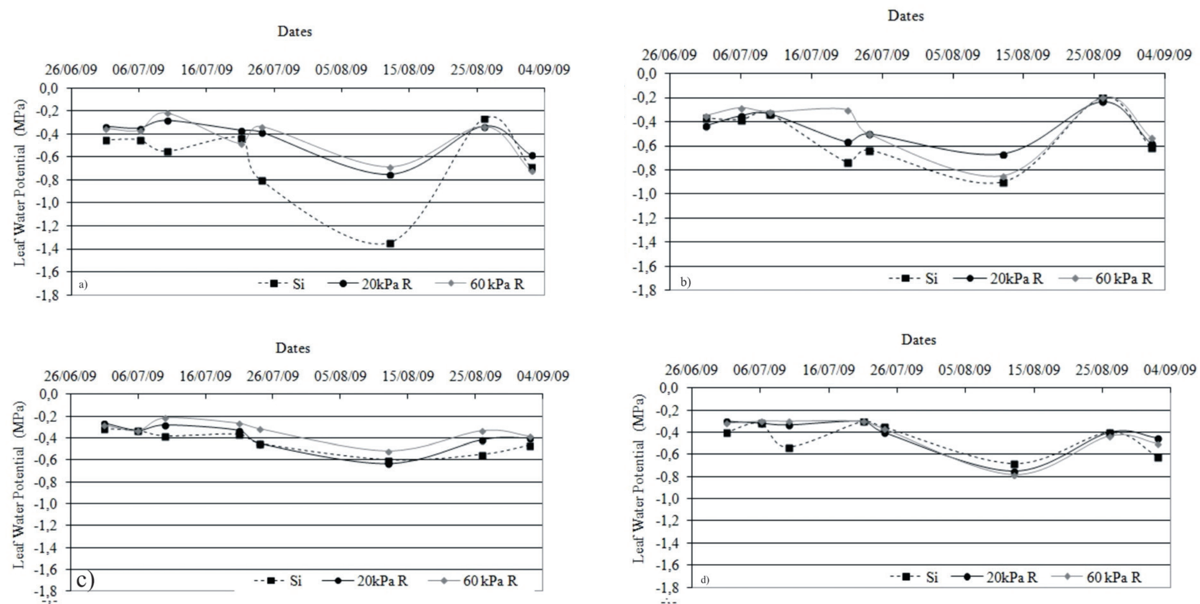

FIGURE 2 - Water leaf Potential (Ψf) of coffee trees not irrigated and irrigated under different hidric regimes in (a) 2500 plants ha^{-1}, (b) 3 333 plants ha^{-1}, (c)5000 plants ha^{-1}, (d) 10000 plants ha^{-1}, for the months of July and August 2009.

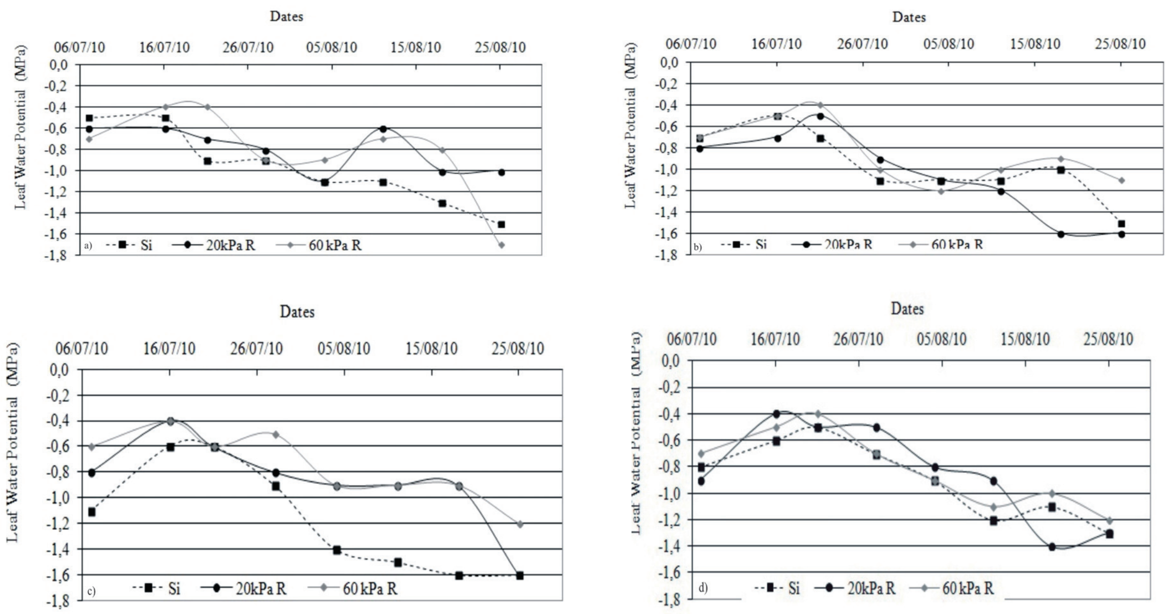

FIGURE 3 - Water Leaf Potential (Ψf) of coffee trees not irrigated and irrigated under different hidric regimes in (a) 2500 plants ha^{-1}, (b) 3 333 plants ha^{-1}, (c) 5000 plants ha^{-1}, (d) 10000 plants ha^{-1} for the months of July and Augdust 2010.

TABLE 3 - Ground volumetric humidity (cm^{-3} cm^{-3}) in layer 0-20 cm, in different planting densities and hidric regimes.

Density (pl. ha^{1})	Hidric regimes	Time of evaluation							
		Jul. 09	Aug09	Sep/Dec09	Jan/Jun10	Jul.10	Aug.10	Sep/dec10	Jan/ May11
		Umidade volumétrica (cm^{-3} cm^{-3})							
2500	Non irrigated	0.274	0.241	0.280	0.275	0.255	0.215	0.305	0.311
2500	20 kPa R	0.299	0.252	0.315	0.402	0.268	0.235	0.309	0.314
2500	60 kPa R	0.320	0.249	0.320	0.317	0.268	0.237	0.307	0.382
3333	Non irrigated	0.248	0.245	0.316	0.341	0.240	0.213	0.307	0.271
3333	20 kPa R	0.257	0.251	0.235	0.349	0.255	0.247	0.327	0.345
3333	60 kPa R	0.258	0.252	0.332	0.353	0.261	0.229	0.334	0.313
5000	Non irrigated	0.269	0.256	0.293	0.314	0.271	0.231	0.328	0.272
5000	20 kPa R	0.317	0.267	0.340	0.432	0.292	0.257	0.322	0.343
5000	60 kPa R	0.308	0.285	0.370	0.348	0.311	0.238	0.352	0.331
10000	Non irrigated	0.296	0.263	0.310	0.436	0.254	0.225	0.316	0.255
10000	20 kPa R	0.341	0.274	0.333	0.325	0.265	0.237	0.315	0.317
10000	60 kPa R	0.317	0.268	0.319	0.318	0.265	0.246	0.319	0.346
Average humidity (cm^{-3} cm^{-3})		**0.292**	**0.259**	0.314	0.351	**0.267**	**0.234**	0.320	0.317
Average rainfall/ period (mm)		**13,6**	**41,9**	211.9	41,0	**19,4**	**1,6**	326,0	97,0

Rezende, Faria and Lismar (2009) observed that in Lavras - MG three years of evaluation, the values of leaf water potential measured before dawn not reached the values that provided the concentration and uniformity of flowering. Within the range of leaf water potential observed, the lowest value is not exceeded -1.5 MPa. According to Goldberg et al. (1988) and Matta et al. (2007), Yf values of up to -1.5 MPa did not seem to affect photosynthesis under field conditions. Although not possibly have occurred effect on photosynthesis, since most months showed values higher than -1.5 MPa may have occurred due to the differences in growth reduction in water potential, whereas water is an essential component for cell expansion (CASTRO; PEREIRA; PAIVA, 2009). Thus, treatments in which plants had higher water potential may be better able to develop and produce normal conditions of water stress.

To the south of Minas Gerais, the adoption of leaf water potential (Yf) of coffee as a benchmark for irrigation and as a basis for recommending periods of water stress does not seem advisable . However, further studies are needed . In the months of lowest rainfall or irrigation in which are suspended , or less dense plantations , where there is a higher incidence of solar radiation are possibly more affected by water stress compared to denser plantings . In the latter , the formation of a humid microclimate seems to maintain a status of water in coffee leaves , even in periods of water stress . Scalco et al. (2003) observed that the values of leaf water potential (Yf) of coffee did not change markedly before and after irrigation , and not due to different densities. The authors found for coffee in the first year of production values of leaf water potential (Yf) not exceeded -1.0 MPa , even in non-irrigated plants .

The use of water for irrigation (Table 2) did not follow the same trend for evaluations in this same area in previous years (PEDROSO et al., 2009), in which increased density provided an increase in water consumption by irrigation due to the increase in the number of plants.

Throughout 2009 and 2010, the applications of water were higher at voltages of 20 kPa, with more frequent irrigations shifts compared to 60 kPa. However, the reduction of spacing (from four to three meters) or between plants (from one to two feet) did not maintain proportional reduction in water consumption for irrigation. However, when the number of plants passes from 2500 to 10,000 plants ha-1, for example, water consumption through irrigation doubling. In leaf water potential effect of these larger water applications may have resulted in the reduction of water stress in denser plantings (Figure 1).

In the two years of evaluation, a significant interaction between the factors planting densities and water regimes in the average production of flowers per pair of reproductive branches of the coffee tree (Table 4 and 5).

In 2009, although the leaf water potential measured in coffee has not reached the value of -2 MPa recommended by Guerra et al. (2007) to provide a water stress on coffee as a way to synchronize flowering in the savanna region, the minimum potential of -1.4 MPa observed in this experiment in the months of July and August was enough to provide greater total production of coffee in flowers conducted in wider spacings and irrigated with respect to coffee plants not irrigated and densified (Figure 2a and 2d and Table 4). The irrigated coffee (considering the average total flowers in schemes 20 kPa and 60 kPa with rest) showed an increase in the average total number of flowers in the order of 64.3% and 933.7% at densities of 2500 and 3333 plants ha-1, respectively, compared to non-irrigated plants. The highest average total production of flowers was detected at a density of 2500 plants ha-1, where there was less leaf water potential in 2009.

In 2010 (Table 5), the lower flower production occurred at a density of 10000 plants ha^{-1}, possibly due to shading, since light is an important factor in the induction of bud to flowering (RENA; MAESTRI, 1986).

The largest flower production occurred in the water regime of 60 kPa with suspending irrigation during the months of July and August (Table 5) . The average production of flowers in this treatment was 116.2 % and 75.5 % higher than the average coffee produced in non- irrigated and irrigated at 20 kPa , respectively for densities of 2500 and 3333 plants ha - 1 . There was no significant difference in flower production per pair of plagiotropic other densities analyzed . In July 2010, 19.4 mm of rainfall occurred in August and it rained only 1.6 mm which could have provided a stronger effect of water stress on flower production . Allied to this , the leaf water potential of coffee was lower (Figures 3 a, b , c , d) in all planting densities and soil moisture also reduced (Table 3) , indicating a greater water stress in July and August 2010. However , even low precipitation can alter the behavior of coffee in relation to flowering , and other factors related to climate (temperature, relative humidity , solar radiation , etc.) and the inherent physiology of coffee production still remains unclear .

Based on the correlation analysis (Table 6) it was found that the values of leaf water potential obtained in the months of July and August (period of suspension of irrigation treatments of 20 and 60 kPa) did not affect the average total production of flowers in both rating the years. In 2009, between July and August, the total rainfall was 55.5 mm, while in 2010 it was 21.0 mm. As mentioned above, even with rainfall during the period of suspension in 2010, the average leaf water potential was lower compared to 2009, indicating a possible effect of water stress. However, the values achieved were not sufficient to induce an effect on flowering.

For density, correlation analysis was significant indicating an inverse relationship between the average number of flowers and the number of plants of plants per hectare. According to Nascimento, Oliveira and Silva (2010), self-shading provides the smallest flowering in super densed systems .

TABLE 4 - Average total production of flowers per pair of plagiotropic branches (2009), in different planting densities and water regimes.

Density (plants ha^{-1})	Non irrigated	60 kPa rest	20 kPa rest	Average density
2500	313bA	565aA	464aA	447A
3333	43bA	489aA	400aA	311B
5000	158aA	317aB	289aB	255B
10000	230aA	166aB	204aB	200B
Regime average	186b	384a	339a	303

Averages followed by the same lowercase and uppercase letters in rows in columns do not differ by cluster test averages Scott-Knott, at 1%.

TABLE 5 - Average total production of flowers per pair plagiotropic (2010), in different planting densities and water regimes.

Density (plants ha^{-1})	Non irrigated	60 kPa rest	20 kPa rest	Average density
2500	193bB	520aB	288bB	334B
3333	650bA	1012aA	503bA	722A
5000	236aB	88aC	91aC	138C
10000	67aB	6aC	13aC	29D
Regime average	287b	407a	224b	306

Averages followed by the same lowercase and uppercase letters in rows in columns do not differ by cluster test averages Scott-Knott, at 1%.

TABLE 6 - Correlations (r) between the Pearson factor planting density and average characteristics of flowers per pair of reproductive branches and leaf water potential (Yf) in 2009 and 2010.

	2009		
Factor/Characteristics	Planting density (plants ha^{-1})	Water Leaf Potential (Ψf)	Average of flowers per pair of plagiotropic branch
Planting density	-	0,25ns	-0,52*
Water Leaf Potential	0,25ns	-	0,05ns
	2010		
Planting density	-	0,26ns	-0,62*
Water Leaf Potential	0,26ns	-	-0,03ns

* Significant at 5% probability by t test.

^{NS} Not significant by t test.

4 CONCLUSIONS

1. The leaf water potential (Yf) of coffee reached lower values in plantations larger than 2500 and 3333 plants $ha^{-1,}$ in relation to planting density of 10,000 plants and 5000 plants ha^{-1}.

2. In planting density of 5000 plants and 10000 plants ha^{-1}, flowering of the coffee is not affected by water regime (irrigated or non-irrigated suspended in July and August).

3. For the south of Minas Gerais, using measures of leaf water potential to quantify the magnitude of water stress need for uniform flowering irrigated coffee is inappropriate due to climatic conditions, especially the occurrence of precipitation in cold months.

5 THANKS

To the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) for financing this project, to CNPq and Consórcio Pesquisa Café for the financial support.

6 REFERENCES

CASTRO, E. M.; PEREIRA, F. J.; PAIVA, R. **Histologia vegetal:** estrutura e função de órgãos vegetativos. Lavras: UFLA, 2009. 234 p.

COELHO, G. et al. Efeito de épocas de irrigação e de parcelamento de adubação sobre a produtividade do cafeeiro 'Catuai'. **Ciência e Agrotecnologia**, Lavras, v. 33, n. 1, p. 67-73, jan./fev. 2009.

CRISOSTO, C. H.; GRANTZ, D. A.; MEINZER, F. C. Effects of water déficit on flower opening in coffee (*Coffea arábica* L.). **Tree Phisiology**, Victoria, v. 10, p. 127-139, 1992.

GOLBERG, A. D. et al. Effects and after-effects of water stress on chlorophyll fluorescence transi-entsin Coffea canephora Pierre and Coffea arabusta Capot and Ake Assi. **Café Cacao Thé**, San José, v. 32, n. 1, p. 11-16, 1988.

GUERRA, A. F. et al. Sistema de produção de café irrigado: um novo enfoque. **Item**, Brasília, n. 63, p. 52-61, 2007.

GUIMARÃES, P. T. G. et al. Cafeeiro. In: RIBEIRO, A. C.; GUIMARÃES, P. T. G.; ALVAREZ, V. H. (Ed.). **Recomendação para o uso de corretivos e fertilizantes em Minas Gerais:** 5ª aproximação. Viçosa, MG: Comissão de Fertilidade do Solo do Estado de Minas Gerais, 1999. p. 289-302.

MATTA, F. M. da. Exploring drought tolerance in coffee: a physiological approach with some insights for plant breeding. **Brazilian Journal of Plant Physiology**, Piracicaba, v. 16, n. 1, p. 1-6, 2004.

MATTA, F. M. da et al. Ecophysiology of coffee growth and production. **Brazilian Journal of Plant Physiology**, Piracicaba, v. 19, n. 4, p. 485-510, 2007.

MATTA, F. M. da; RENA, A. B. Ecofisiologia de cafezais sombreados e a pleno sol. In: ZAMBOLIM, L. (Ed.). **O estado da arte e tecnologia na produção de café**. Viçosa, MG: UFV, 2002. p. 93-135.

MORGAN, J. M. Adaptation to water deficits in three grain legume species: mechanisms of turgor maintenance. **Field Crops Research**, Amsterdam, v. 29, p. 91-106, 1991.

NASCIMENTO, L. M. do; OLIVEIRA, C. A. S.; SILVA, C. L. Paralisação da irrigação e sincronia do desenvolvimento das gemas reprodutivas de cafeeiros *(Coffea arabica* L.) orgânico e adensado. **Coffee Science**, Lavras, v. 5, n. 2, p. 107-112, 2010.

NOGUEIRA, R. J. M. C. et al. Alterações na resistência à difusão de vapor das folhas e relações hídricas em aceroleiras submetidas a déficit de água. **Revista Brasileira de Fisiologia Vegetal**, Londrina, v. 13, p. 75-87, 2001.

OLIVEIRA, L. A. M. **Desenvolvimento vegetativo e reprodutivo do cafeeiro (*Coffea arábica* L.) irrigado em diferentes épocas do ano**. 2003. 54 p. Dissertação (Mestrado em Engenharia Agrícola) - Universidade Federal de Lavras, Lavras, 2003.

OLIVEIRA, P. M. de. **Florescimento do cafeeiro (*Coffea arabica* L.) sob diferentes frequências de irrigação**. 2002. 67 p. Tese (Doutorado em Fitotecnia) - Universidade Federal de Lavras, Lavras, 2002.

PEDROSO, T. Q. et al. Qualidade de sementes de cafeeiro produzidas em diferentes densidades de plantio e regimes hídricos. **Coffee Science**, Lavras, v. 4, n. 2, p. 155-164, jul./dez. 2009.

RENA, A. B.; MAESTRI, M. Fisiologia do cafeeiro. In: RENA, A. B. et al. (Ed.). **Cultura do cafeeiro:** fatores que afetam a produtividade. Piracicaba: Associação Brasileira para Pesquisa da Potassa e do Fosfato, 1986. p. 13-106.

______. Relações hídricas no cafeeiro. **Item**, Brasília, n. 48, p. 64-73, 2000.

REZENDE, F. C.; FARIA, M. A. de; LISMAR, W. Efeitos do potencial de água da folha na indução da floração e produção do cafeeiro (*Coffea arabica*, L.). **Coffee Science**, Lavras, v. 4, n. 2, p. 126-135, jul./dez. 2009.

SANTINATO, R.; FERNANDES, A. L. T. **Cultivo do cafeeiro irrigado em plantio circular sob pivô central**. Belo Horizonte: O Lutador, 2002. 252 p.

SCALCO, M. S. et al. Potencial hídrico foliar do cafeeiro sob diferentes critérios de irrigação e densidades de plantio. In: SIMPÓSIO DE PESQUISA DOS CAFÉS DO BRASIL, 3., 2003, Porto Seguro. Anais... Brasília: EMBRAPA café, 2003. p. 143.

SILVA, A. M. et al. Produtividade, rendimento de grãos e comportamento hídrico foliar em função da época de irrigação do parcelamento e do método de adubação do cafeeiro Catuaí. Engenharia Agrícola, Jaboticabal, v. 23, n. 3, p. 434-440, 2003.

SILVA, C. A. da et al. Produtividade e potencial hídrico foliar do cafeeiro 'Catuai' em função da época de irrigação. Revista Brasileira de Engenharia Agrícola e Ambiental, Campina Grande, v. 12, n. 1, p. 21-25, 2008.

SILVA, C. A. da; TEODORO, R. E. F.; MELO, B. de. Produtividade e rendimento do cafeeiro submetido a lâminas de irrigação. Pesquisa Agropecuária Brasileira, Brasília, v. 43, n. 3, p. 387-394, mar. 2008.

SILVA, E. A. da et al. Influência de déficits hídricos controlados na uniformização do florescimento e produção do cafeeiro em três diferentes condições edafoclimáticas do estado de São Paulo. Bragantia, Campinas, v. 68, n. 2, p. 493-501, 2009.

SOARES, A. R. et al. Irrigação e fisiologia em cafeeiros adultos na região da zona da mata de Minas Gerais. Acta Scientiarum Agronomy, Maringá, v. 27, n. 1, p. 117-125, 2005.