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SECAMENTO PARCIAL DA ZONA RADICULAR NA BANANEIRA 'GRAND NAINE' NO SEMIÁRIDO DO NORTE DE MINAS GERAIS

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1 RESUMO

A irrigação com déficit que permite a redução de até 50% do dispêndio de água é uma alternativa cuja viabilidade deve ser uma meta de alcance nas pesquisas. Portanto, este trabalho objetivou definir a viabilidade do uso do método do secamento parcial da zona radicular para a bananeira cultivar 'Grand Naine' nas condições edafoclimáticas do Norte de Minas Gerais. O estudo avaliou três frequências de alternância do lado irrigado da fileira de plantas somadas à condição de irrigação de um só lado, todos com redução de 50% da lâmina de irrigação calculada e com ambos os lados da fileira de plantas irrigados com 100% da lâmina calculada. Foram avaliados os indicadores de manejo de água do solo e a condutância estomática das folhas dos tratamentos, além das variáveis de produção e de qualidade de frutos. Os resultados indicaram a viabilidade do uso do secamento parcial da zona radicular para a bananeira cultivar 'Grand Naine' com redução da lâmina de irrigação de 50% e frequência de alternância do lado irrigado da fileira de plantas de 7 e 14 dias. A qualidade pós-colheita dos frutos não foi influenciada pelos estresses hídricos temporários do solo resultantes dos tratamentos.

Palavras-chave: *Musa* spp., déficit hídrico, manejo da irrigação.

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2 ABSTRACT

The deficit irrigation allows the reduction of about 50% of the water use and is an alternative whose feasibility should be a goal for research. Thus, this work aimed to define the feasibility of using of the partial root-zone drying for banana cv Grand Naine under the edaphoclimatic conditions of the Northern of Minas Gerais. The study evaluated three frequencies of irrigated-

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side shifting of plant row, added up to one-sided irrigation condition, all sides with reduction of 50% of the irrigation blade calculated and with both sides of the plants row irrigated with 100% of the irrigation blade calculated. Soil and water management indicators and leaf stomatal conductance of the treatments were evaluated and variables of production and post-harvest fruit quality, as well. Results indicated the feasibility of the use of partial root-zone drying for banana cv grand Naine with 50% reduction of irrigation blade and frequencies of 7 and 14 days for irrigated-side shifting of plant row. The post-harvest fruit quality was not influenced by the transient water stress provided by treatments.

Keywords: *Musa* spp., water deficit, irrigation management.

3 INTRODUCTION

The main projections of global warming and climate change predict an increase in air temperature, severe droughts in some regions of the planet (EDENHOFER et al., 2014) and an increase in water demand for crops due to the increase in maximum or reference evapotranspiration (DIAS; SUASSUNA, 2016). This new climate condition will cause greater problems in regions with a consolidated history of droughts and significant fruit production, such as the semiarid region of northern Minas Gerais, where one of the largest banana production centers in Brazil is located.

Banana cultivation in Brazil has resulted in a loss of area in northern Minas Gerais in recent years, as well as reduced production due to decreased profitability, the incidence of "Panama disease," and adverse weather conditions related to high temperatures and a reduced water supply. The area cultivated with bananas in northern Minas Gerais, recorded in 2019, was 29,056 ha (HACKMANN; OLIVEIRA; BARBIERI, 2020). This area produces irrigated bananas and is dependent on water sources such as the São Francisco River, whose water availability is linked to rainfall patterns.

Given the expected increase in area needs in the coming years (NATIONAL WATER AGENCY, 2017), irrigation, as the largest consumer of freshwater, requires effective changes in irrigators' water use to preserve water resources. These changes imply the application of existing irrigation water management methods, such as root zone water balance or the use of sensor-based soil water requirement indicators in conjunction with the retention curve and moisture content or critical tension (COELHO et al., 2012), as well as other methods that, despite being well known, are not generally used by irrigators. These changes also imply the use of unconventional water management methods that employ deficit irrigation. Among deficit irrigation methods, the partial root-zone drying (PRD) method has been identified as a successful alternative for reducing water consumption in irrigated fruit farming (COELHO et al., 2019; SANTOS et al., 2021).

Partial root drying involves alternating the irrigation side of the root system. While part of the root system is irrigated to maintain adequate water status in the plant, the other part of the root system is subjected to drying (PÉREZ-PÉREZ et al., 2018). The theory is that roots subjected to drying produce chemical signals (abscisic acid and ethylene), which reduce the stomatal aperture, thus decreasing transpiration (EL-SADEK, 2014). Maintaining the photosynthetic rate associated with reduced transpiration increases water use efficiency (SANTOS et al., 2021). Despite the numerous promising results of the PRD method for irrigated fruit growing in semiarid regions (SANTOS et al., 2021; COELHO et al., 2019), there is a lack of information on its feasibility under specific climate, soil, and crop conditions associated with the percentage of irrigation depth reduction and frequency of irrigation side alternation. Therefore, the objective of this study was to define the feasibility of using the partial root zone drying method for 'Grand Naine' banana under semiarid conditions in northern Minas Gerais.

4 MATERIALS AND METHODS

The experiment was conducted at the Gorutuba Experimental Farm belonging to the Minas Gerais Agricultural Research Corporation (EPAMIG), in the municipality of Nova Porteirinha, MG, with the following central coordinates: 15° 48' 15" S and 43° 18' 0" W. The soil in the area was classified as Red–Yellow Latosol (EMBRAPA, 2013), whose physical–hydric characteristics are presented in Table 1.

Table 1. Physical and water characteristics of the soil in the experimental area.

Prof. (m)	Sand ----	Silt $KgKg^{-1}$	Clay ----	Dens. soil $Kgdm^{-3}$	Humidity ($cm^3 cm^{-3}$)		Water available (mm)
					-10 kPa	-1500 kPa	
0–0.2	483	234	283	1.71	0.22	0.17	9.2
0.2-0.4	444	263	293	1.66	0.26	0.23	5.2

Prof. = Depth; Dens. = Density; Humid. = Humidity

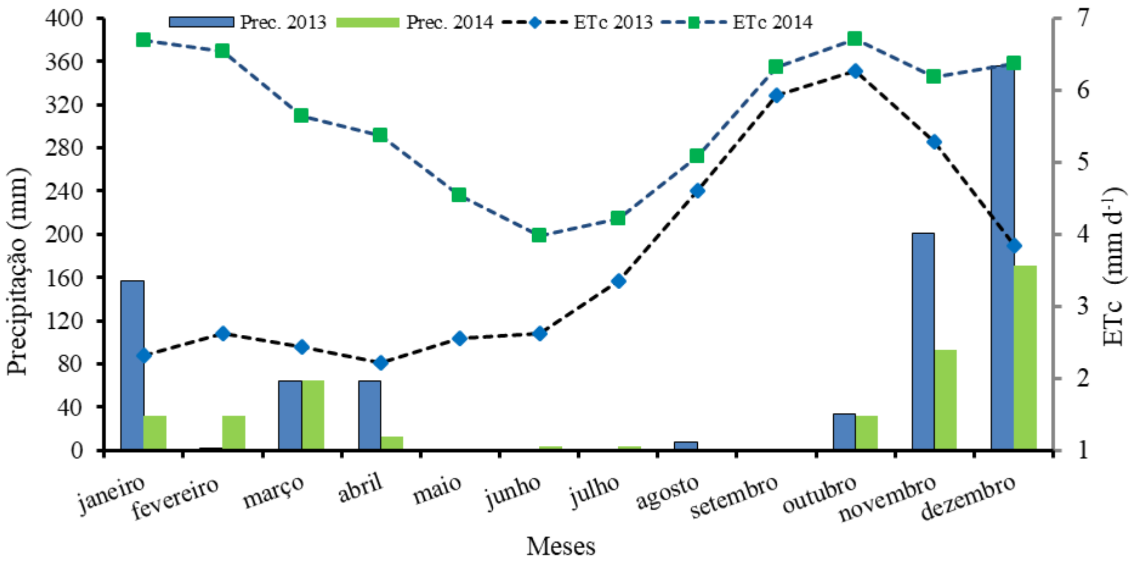
The 'Grand Naine' banana plant was grown at a spacing of 2.5 m × 2.0 m in two cycles, one from February 2013 to February 2014 and the other from February to December 2014. The experiment followed a randomized complete block design with five treatments and five replicates. The treatments were based on a 50% reduction in the calculated irrigation depth (LIC) (with one lateral line irrigated per row) and the frequency of alternating the irrigated side of the row. The alternation frequencies, F, i.e., the intervals between changing the irrigated side, were 7, 14, and 21 days. The treatments were as follows: T1, 50% reduction in LIC, with an F of 7 days; T2, 50% reduction in LIC, with an F of 14 days; T3, 50% reduction in LIC, with an F of 21 days; T4, 50% reduction in LIC, with only one side irrigated throughout the cycle; and T5, full irrigation, i.e., an irrigation depth corresponding to the total LIC replacement, with both lateral lines per plant row operating simultaneously during each irrigation event. The maximum, minimum, and average monthly temperatures, as well as the vapor pressure deficit during the two banana growth cycles, can be seen in Table 2.

Table 2. Monthly average values of air vapor pressure deficit (DPV) and meteorological variables: maximum (Tmax), minimum (Tmin) and average (Tmed) temperatures throughout the months of the experiment at Nova Porteirinha, MG.

Months	Year: 2013				Year: 2014			
	Tmax (°C)	Tmin (°C)	Tmed (°C)	DPV (kPa)	Tmax (°C)	Tmin (°C)	Tmed (°C)	DPV (kPa)
Jan	32.83	21.18	25.52	1,2	33.08	20.05	26.14	1.4
Feb	34.12	19.77	26.73	1.76	33.68	20.69	26.45	1.53
Sea	28.55	21	27.77	1.59	32.35	21	26.16	1.21
Open	31.95	20.7	25.35	1.15	33.41	20.36	26.18	1.43
May	32.73	18.49	23.92	1.32	32.27	19.16	24.93	1.45
June	30,35	17.68	23.43	1.35	30.45	17.78	23.39	1.25
Jul	30.91	16.96	23.55	1.42	30.59	16.9	22.95	1.3
Aug	31.48	16.94	24.13	1.54	31.51	16.69	23.79	1.65
Set	33,31	19.27	25.79	1.67	33.71	17.58	25.49	1.92
Out	33.14	20.29	26.1	1.68	34.05	19.76	26.82	2.01
Nov	33.25	20.86	26.47	1.53	32,33	20.84	26.18	1.36
Ten	29.83	20.89	24.5	0.61	32.22	20.08	25.65	1.28

The accumulated rainfall was 884 mm in the first cycle (2013) and 443.4 mm in the second cycle (2014). During the two periods of the experiment, the highest monthly values of accumulated precipitation were observed in December, with 355.2 mm in 2013 and 170.8 mm in 2014 (Figure 1). The average values of evapotranspiration during the two cycles are presented in Figure 1.

Figure 1. Monthly rainfall and evapotranspiration of the 'Grand Naine' banana tree during the experiment at Nova Porteirinha, MG.



Irrigation was applied via a drip system with two lateral lines per row of plants, with emitters spaced 0.50 m apart, totaling eight emitters per plant. Irrigation water management followed a daily frequency, with crop evapotranspiration replenishment determined from the maximum evapotranspiration calculated by the Penman–Monteith equation modified by the FAO (ALLEN et al., 1998). Reference evapotranspiration was calculated daily on the basis of data provided by the automatic meteorological station of the National Institute of Meteorology (INMET, Code: A563). The crop coefficients used to calculate the irrigation depth in the first year were 0.4, 0.45, 0.5, 0.6, 0.7, 0.85, 1.0, 1.0, 0.9, and 0.8 (ALLEN et al., 1998). In the second year, the cultivation coefficient used was 1.1 (COELHO et al., 2006). The water depth calculated for each irrigation event was obtained daily via data from reference evapotranspiration (mm d^{-1}), the cultivation coefficient, the location coefficient (FERERES, 1981) and the efficiency of the drip system (considered to be 90%).

Plant growth assessments, including plant height, pseudostem diameter at 0.20 m above the ground, and leaf area, were performed via the methods of Zucoloto, Lima, and Coelho (2008) at the beginning of the cycle and during the flowering period. Stomatal conductance measurements were taken in July 2014 and September 2014 via a porometer, model SC-1 (Decagon Devices), on the third leaf between 9 and 10 a.m. Soil moisture was assessed at least every 15 days on both sides of the plant rows, 0.10 m from the dripper in the 0–0.20 m layer, via a capacitance probe (Model Diviner 2000®) between the emitter and the plant in a block during the second cycle.

The production variables, bunch yield, hand yield, and the length and diameter of the median fruit of the second hand, were recorded during the harvest period. The bunch yield was determined by summing the weight of the bunches per treatment, and the product of this sum was multiplied by the number of plants corresponding to one hectare. The hand yield was determined on the basis of the bunch yield but not the weight of the stalk. Water use efficiency was obtained according to the methodology used by Coelho et al. (2019).

The fruits were evaluated after harvest. The first evaluation was at the point of harvest, with green skin but physiologically developed, and the second when they reached stage 6 of ripening, according to the classification standards of the Companhia de Entrepostos e Armazéns Gerais de São Paulo - CEAGESP (BRAZILIAN PROGRAM FOR MODERNIZATION OF HORTICULTURE AND INTEGRATED FRUIT PRODUCTION, 2006), which uses the Loesecke scale. During the ripening period (from harvest point to stage 6), the fruits remained on the bench in the postharvest laboratory at a room temperature of 26 ± 1°C. The effects of the treatments on the quality of the fruits were studied through physical and chemical evaluations at the point of harvest or ripening, as described below: 1 – mass of the bouquet of pulp and skin: the different parts were weighed on a digital scale, and the values expressed in g. To determine the bouquet mass (fruit plus cushion), three fruits still attached to the cushion were weighed, and subsequently, the fruits were removed from the cushion and the peel and pulp were weighed separately; 2 - pulp/peel ratio: the ratio consists of the relationship between the pulp mass and the peel mass; 3 - peel color: evaluation performed with the aid of a Konica CR-400 colorimeter, through which the color is expressed by luminosity (L), chromaticity (C) and color angle (°hue); 4 - firmness: determined in the median region of the fruit with peel with the aid of a digital bench penetrometer, expressed in N; 5 - soluble solids: determined by refractometry according to the methodology of the Adolfo Lutz Institute (IAL) (ZENEBON;

PASCUET; TIGLEA, 2008), expressed in °Brix; and 6 - titratable acidity: determined by titrim The length and diameter were evaluated only at the harvest point via a digital caliper and are expressed in cm and mm, respectively.

Statistical analyses consisted of an analysis of variance (ANOVA) using a randomized block design with five treatments and five replicates. The sources of variation were qualitative, i.e., involving both water reduction and alternation frequency, with the control treatment (no LIC reduction and permanent irrigation on both sides of the row). In this analysis, the effects of the treatments on the dependent variables were assessed via Tukey's mean test with a 5% confidence level. Another analysis was performed considering only the four treatments with a 50% LIC reduction and alternation frequencies of the irrigated side of the row: 0 (no change in the irrigated side of the row), 7, 14, and 21 days of intervals between the irrigated side of the row. In this case, the frequency of changing the irrigated side of the row was considered a quantitative variable. For postharvest evaluations, a completely randomized design was used, with five treatments and five replicates of three fruits per plot. A general analysis of variance (ANOVA) was performed, with treatment as the cause of variation. Before the ANOVA, the Lilliefors test was performed to assess the normal distribution of errors.

5 RESULTS AND DISCUSSION

5.1 Climatic and soil water conditions under water management by partial root zone drying (PRD)

In both cycles, the crop water requirements were similar, with a difference of 105 mm more in the second cycle, whereas the precipitation in the second cycle was 52% of that in the first cycle, with the water deficit in the second cycle being the same magnitude as that in the first cycle. In both banana cycles, most of the annual precipitation occurred during the flowering and fruit growth phases, although crop evapotranspiration was lower at all phenological stages (Table 3). Evapotranspiration was more pronounced during the fruit growth phase in both cycles (Figure 1), not only because of the greater water demand at this stage but also because meteorological conditions (higher temperatures and air DPV, Table 2) are more favorable for greater evapotranspiration.

Table 3. Precipitation (Precip; mm), maximum reference evapotranspiration (ETo; mm), crop evapotranspiration (ETc; mm), deficit (Precip-ETc; mm) and total depths applied in treatments without LIC reduction (L - 100%; mm) and with 50% LIC reduction (L - 50%; mm), Nova Porteirinha, MG.

Months	Cycle	Phase of Culture	Precip	ETo	Etc	Precipit-Etc	L 100%	L 50%
Feb-Apr/2013	1	Cres. v.	130 (16%)	458	176 (10%)	-46	221	110.5
May-Sep/2013	1	Cres. v.	8 (1%)	662	663 (39%)	-655	781	390.5
Oct/2013-Feb/2014	1	Cres. f.	653 (83%)	845	879 (51%)	-226	643	321.5
Total in the cycle	1		791	1965	1718	-927	1645	822.5
Feb-Apr/2014	2	Cres. v.	109 (26%)	467	499 (27%)	-390	458	229
May-Sep/2014	2	Cres. v.	8 (2%)	668	733 (40%)	-725	905	452.5
Oct-Dec/2014	2	Cres. f.	295 (72%)	537	591 (32%)	-296	768	384
Total in the cycle	2		412	1672	1823	-1411	2131	1065.5

Cres. v. = Vegetative growth; Cres. f. = Fruit growth

The average soil moisture on the irrigated side of the plant rows was equal to or close to the upper limit of available water in all the treatments, whereas on the nonirrigated side, the average moisture was close to the upper limit of available water only in Treatment 1 (50% LIC reduction with alternation frequency of the irrigated side of the row of 7 days). On the nonirrigated side of the plant row in the treatments with a 50% LIC reduction, the average moisture was close to the lower limit of available water for treatment T3 (alternation frequency of 21 days) and below it in treatment T4 (with only one side permanently irrigated). In the treatment with an alternation frequency of 14 days, the average moisture content was 49% of the available soil water (Table 4).

Table 4. The average soil moisture on each side of the plant row was averaged on both sides for the partial drying treatments of the banana root zone.

Plant row side	T1	T2	T3	T4	T5
Drying	0.2124a	0.1949a	0.1705b	0.0997b	0.2091a
Irrigated	0.2424a	0.2002a	0.2152a	0.2252a	0.2091a
Average of the sides	0.2274a	0.1975b	0.1928b	0.1675c	0.2092a

Means followed by the same letters in the same column do not differ statistically by the Tukey test at a 5% level of significance.

5.2 Growth, productivity and water use efficiency

In the case of the growth variables, significant differences occurred in the second cycle, with no difference between the means in the first cycle. In the second cycle, the means for plant height (ALTPLAN), pseudostem diameter (DPCAULE), and leaf area (AFOLIAR) of treatments T1, T2, and T5 did not differ from each other and were statistically greater than the means of treatments T3 and T4 (Table 5). In the second crop cycle, during the dry period of the year, from May--September--October, in addition to the almost zero rainfall during the period, the monthly vapor pressure deficit was greater, which may have influenced the soil water absorption regime of the plants subjected to the treatments with a greater 50% reduction in LIC compared with the conditions of the first cycle. This phenomenon was aggravated in the treatments with a lower frequency of alternation of the irrigated side of the plant row, that is, in treatment T3 (21 days of alternation frequency) and in T4, with 50% of the LIC on only one side of the plant row. In these treatments, the reduction in water absorption by the roots on the nonirrigated side negatively influenced plant height, pseudostem diameter and leaf area (Table 5).

Table 5. Averages of the growth variables of the banana 'Grand Naine': number of leaves (NFOLHA), plant height (ALTPLAN, m), pseudostem diameter (DPCAULE, m) and leaf area (AFOLIAR, m ^{2}).

Treatments	SHEET		ALTPLAN		DPCAULE		Afoliate	
	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2	Cycle 1	Cycle 2
T1	13.45 a	13.88 a	2.14 a	2.81 a	0.2060 a	0.80 to	11.04 a	15.56 a
T2	14.09 a	13.86 a	2.17 a	2.79 a	0.2054 a	0.79 to	11.34 a	14.88 ab
T3	14.11 a	13.24 a	2.11 a	2.58 b	0.2106 a	0.73 b	11,12 a	13.88 b
T4	13.61 a	12.15 b	2.03 a	2.46 b	0.1970 to	0.69 b	10.12 a	12.10 c
T5	14.28 a	14.01 a	2.17 a	2.82 a	0.2094 a	0.81 to	11.42 a	15.46 a
General Doctor	13.91	13.43	2.12	2.69	0.2056	0.76	11	14.37
CV (%)	4	4.08	4.57	3.21	4.14	2.83	10.04	3.77

Means followed by the same letters in the same column do not differ statistically according to Tukey's test at the 5% significance level. T1 - PRD 7 days; T2 - PRD 14 days; T3 - PRD 21 days; T4 - 50% water deficit and T5 control treatment.

The analysis of variance did not detect an effect of the treatments for the variable number of fruits (NFRUTO), average fruit weight (PESOM), length (COMFR) or fruit diameter (DIAMF) in the first cycle (Table 6). The effect of the treatments was detected only for fruit productivity (PPENCA), which was due to the difference between all the treatments, which did not differ from each other, and treatment 4, which had the lowest productivity.

The lower productivity of the T4 treatment in the first cycle was due to the lower number of fruits and the lower average fruit weight (Table 6), possibly due to the lack of alternating irrigated sides and the 50% reduction in the irrigation depth. In the second cycle, there was no effect of the treatments on handicraft productivity, which ranged from 46.80 to 53.28 t ha $^{-1}$. The treatments affected only the number and length of fruits (Table 6). The means of these variables for the T5, T2, and T1 treatments did not differ from each other and were higher than the means of the T3 and T4 treatments, with the lowest means observed in the T4 treatment (Table 6). These results are consistent with the results of the plant growth variables, i.e., plant height, pseudostem diameter, and leaf area, which were lower for the T3 and T4 treatments. The reduction in productivity of treatments T3 and T4 was directly related to the lower frequency of alternation of the irrigated side (T3 - 21 days) and irrigation on only one side of the plant row (T4), leading to lower water availability on the side subjected to drying and, consequently, to a lower rate of water absorption by the roots (COELHO et al., 2019).

Table 6. Averages of the production variables of the banana tree 'Grand Naine': bunch productivity (PPENCA, t ha $^{-1}$), number of fruits per bunch (NFRUTO), average fruit weight (PESOMED, g), average fruit length (COMFR, cm) and average fruit diameter (DIAMFR, cm).

Trat.	PPENCA		FRUITS		PESOMED		COMFR		DIAMFR	
	Cic.1	Cic.2	Cic.1	Cic.2	Cic.1	Cic.2	Cic.1	Cic.2	Cic.1	Cic.2
T1	43.2a	49.1a	124.0a	158.0ab	174.4a	169.2a	23.5a	24.4ab	4.2a	4.1a
T2	43.5a	53.3a	123.6a	164.8a	176.8a	169.9a	23.6a	24.3ab	4.3a	3.8a
T3	42.6a	50.2a	131.0a	150.0ab	172.5a	165.2a	23.8a	23.3ab	4.2a	4.0a
T4	35.5b	48.2a	112.8a	139.2b	161.0a	161.1a	22.4a	22.9b	4.1a	4.00a
T5	46.9a	46.8a	132.6a	165.0a	177.0a	181.4a	24.3a	24.8a	4.2a	4.1a
CV (%)	7.26	11.06	9.36	7.47	5.94	6.37	4.64	4.1	2.71	3.39

Means followed by the same letters in the same column do not differ statistically according to Tukey's test at the 5% significance level. T1 - PRD 7 days; T2 - PRD 14 days; T3 - PRD 21 days; T4 - 50% water deficit and T5 control treatment.
Cic. = Cycle

Some analyses of variance in relation to stomatal conductance revealed a significant effect of treatment (Table 7). The analysis of variance (date: 06/07/2014) did not reveal a significant effect of treatment on stomatal conductance (gs) because of the high coefficient of variation (Table 7). The average gs was greater for treatment T5 (without a reduction in LIC) and lower for treatments T3 and T4 in three of the four evaluations performed (Table 7). Santos et al. (2017), when cultivating the banana tree 'BRS Princesa' in semiarid conditions and under PRD, also reported greater reductions in stomatal conductance in plants irrigated with 50% ETc with fixed irrigation on one side of the plant, especially during the period of greatest stress for banana trees in the region. The 50% reduction in LIC associated with the frequency of alternating the irrigated side of the 21-day plant row and without alternating the irrigated side resulted in greater soil water stress on the nonirrigated side (Table 4). Higher gs values are related to greater crop transpiration. Transpiration is directly related to photosynthesis, which in turn is directly related to productivity (SANTOS et al., 2021).

Table 7. Average values of stomatal conductance (gs) in mmol m $^{-2}$ s $^{-1}$ of 'Grand Naine' banana for different periods under five irrigation treatments.

Treatments	Date			
	06/07/2014	07/22/2014	July 24, 2014	September 26, 2014
T1	228.5	191.2 bc	304.3 a	228.0 ab
T2	266.2	257.0 ab	209.7 b	232.4 ab
T3	164	57.0 d	48.7 c	125.7 b
T4	52.7	111.8 cd	188.0 b	123.0 b
T5	132	314.0 a	242.3 ab	308.5 a
CV (%)	65.16	28.8	19.5	28.5

Means followed by the same letters in the same column do not differ statistically according to Tukey's test at the 5% significance level. T1 - PRD 7 days; T2 - PRD 14 days; T3 - PRD 21 days; T4 - 50% water deficit and T5 control treatment.

The water use efficiency (WUE) for the treatments with a 50% LIC reduction and alternating frequencies of irrigated row sides of 7, 14, and 21 days and with irrigation on only one side of the row of plants did not differ from each other and were greater than the means of the treatment without LIC reduction (100% LIC). The mean WUE of the 'Grand Naine' banana in the treatments with a 50% LIC reduction in both cycles was between 45.78 kg mm $^{-1}$ and 60.9 kg mm $^{-1}$, which was higher than the mean WUE of the treatment without LIC reduction (T5), which reached a WUE of 41.74 kg mm $^{-1}$ in the first cycle and 39.96 kg mm $^{-1}$ in the second cycle (Table 8). In the first cycle, the mean WUE of the T5 treatment did not differ from that of the other treatments and, in absolute value, was 30% and 28% lower than the means of T1 and T2, respectively. In the second cycle, the average EUAs for T1 and T2 were 28% and 33% higher than those for T5 (Table 8). This information, combined with the average yields of these treatments, indicates that treatments with a 50% reduction in the water depth and alternating frequencies of the irrigated side of the row of 7 and 14 days present the best agronomic performance.

Table 8. Water use efficiency (water productivity) in kg mm $^{-1}$ for the PRD treatments in the two cycles of 'Grand Naine' banana plants.

Treatments	2013	Treatments	2014
T4- 50% LIC- Alt. 0 days	60.90 to	T4- 50% LIC- Alt. 0 days	57.06 a
T1- 50% LIC- Alt. 7 days	59.46 a	T1- 50% LIC- Alt. 7 days	53.30 a
T2- 50% LIC- Alt. 14 days	57.46 a	T2- 50% LIC- Alt. 14 days	51.46 ab
T3- 50% LIC- Alt. 21 days	52.48 ab	T3- 50% LIC- Alt. 21 days	45.78 ab
T5- 100% LIC	41.74 b	T5- 100% LIC	39.96 b
CV (%)	11.9		12.7

Means followed by the same letters in the same column do not differ statistically by the Tukey test at a 5% level of significance.
Alt. = alternation

5.3 Postharvest fruit quality

'Grande Naine' bananas produced under a 50% reduction in irrigation depth, with or without alternating the irrigated side of the row, or under full irrigation did not differ statistically in terms of the variables evaluated at harvest or when ripe. The mean values of bouquet weight, pulp weight, peel weight, peel color, the pulp/peel ratio, soluble solids, firmness, titratable acidity, length, and diameter are presented in Tables 9 and 10. The bouquet weights of three fruits at harvest and when ripe were 507.30 g and 437.29 g, respectively, a 13.8% reduction in initial weight (Table 9). Fresh mass loss is common during banana ripening and is influenced by storage temperature and humidity and biotic and abiotic factors. According to Sarmento et al. (2015), fresh mass loss occurs because of the consumption of nutrients during metabolism itself and mainly because of water loss caused by transpiration processes and the difference in pressure between the fruit and the environment. However, the weight gain observed in the pulp (Table 9) is likely due to hydration promoted by water loss from the peel, not only to the pulp but also to the environment. According to Matsuura and Folegatti (2001), pulp sugars increase more rapidly during ripening than those in the peel do, contributing to a differential change in osmotic pressure, leading to water absorption by the pulp.

The mass, in turn, was reduced by 35.3% in the ripe fruits compared with the peel weight at harvest (Table 9), indicating dehydration. The pulp/peel ratio reflects the opposite trend of pulp mass gain and peel loss and increases in ripe fruits. This ratio affects fruit yield in industry and is known as the "ripening coefficient," which is considered an index of maturity (MATSUURA; FOLEGATTI, 2001). Fruit peel color is represented in Table 9 by the parameters °hue, L, and C. Between harvest and ripe fruits, a reduction in °hue indicates degreening, with an increase in luminosity (L), since the yellow hue is lighter than the green hue and in color intensity, with higher chroma (C) values.

Table 9. Averages of the variables evaluated in 'Grand Naine' bananas at harvest and ripe produced under partial root drying.

'Grand Naine' bananas ready for harvest						
Bouquet Mass [1] (g)	**Pulp mass [1] (g)**	**Mass [1] of the shell (g)**	**L**	**W**	**° hue**	**Pulp/Peel**
507.30	288.30	213.99	56.33	41.59	119.27	1.36
Ripe 'Grand Naine' bananas						
437.29	309.06	138.48	68.35	50.47	95.36	2.39

[1] Mass of three fruits; L = Luminosity and C = Chroma.

The values of soluble solids, firmness, and titratable acidity of the fruits at harvest and ripening, as well as their length and diameter at harvest, are presented in Table 10. Both soluble solids and titratable acidity increased in ripe fruits compared with those at harvest. The soluble solids content of ripe fruits is close to that reported by Nobre et al. (2018) for 'Nanica' banana, which also belongs to the Cavendish subgroup, such as 'Grande Naine', ranging from 7.62--7.72° Brix, depending on storage conditions. According to the authors, the increase in total soluble solids content during ripening is attributed mainly to the hydrolysis of reserve carbohydrates accumulated during fruit growth on the plant. The tendency for titratable acidity to increase with ripening is common in bananas and was also observed by Matsuura and Folegatti (2001).

Compared with that at harvest, firmness decreased significantly in ripe fruits, as shown in Table 10. At harvest, bananas had a value of 37.94 N, and when ripe, firmness decreased to 3.49 N. Firmness naturally decreases with ripening due to the action of cell wall-degrading enzymes, whose activity increases or is activated at this stage of development. According to Mohapatra et al. (2011), fruit softening may also be associated with increased pulp moisture due to osmotic exchanges with the peel, resulting in loss of turgor. This is in addition to starch hydrolysis and solubilization of pectic substances in the cell wall.

On the basis of the classification standards of CEAGESP (BRAZILIAN PROGRAM FOR THE MODERNIZATION OF HORTICULTURE AND INTEGRATED FRUIT PRODUCTION, 2006), the fruits (Table 10) are in the extra category, as they have a diameter greater than 32 mm, which is required for classification in this category, and in class 18, which includes lengths >18 cm to 22 cm.

Table 10. Averages of the variables evaluated in 'Grand Naine' bananas at harvest and ripe produced under partial drying of the root system.

Soluble solids (°Brix)	Firmness (N)	Acidity (% malic acid)	Length (cm)	Diameter (mm)
'Grand Naine' bananas ready for harvest				
0.91	37.94	0.19	21.90	39.98
Ripe 'Grand Naine' bananas				
7.85	3.49	0.41	-	-

6 CONCLUSIONS

The use of irrigation water management by partial drying of the root zone is viable for the banana cultivar 'Grand Naine', which has a 50% reduction in volume or total irrigation depth with alternating frequencies of the irrigated side of the plant row of 7 and 14 days.

The treatments with a 50% reduction in the water depth and alternation frequency on the irrigated side of the row for 7 and 14 days presented the best agronomic performance.

The quality of the fruits of the 'Grand Naine' banana tree at harvest or ripening did not suffer because of the 50% reduction in the volume or irrigation depth associated with the frequencies of 7, 14 and 21 days of changing the irrigated side of the plant row during the crop cycle.

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